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THE AUTHORS OF THE SEVERAL PAPERS ARE SEVERALLY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

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Art I.—*Bitter Pit in Apples.*

By JEAN WHITE, D.Sc.,

Government Research Scholar, University of Melbourne.

(With Plates I.-IX.).

[Read 11th May, 1911].

About the middle of 1910 attention was attracted by the newspapers to the common occurrence of this disease in some of our Australian fruits. Owing to the fact that it apparently developed during the transit of the fruits, however carefully they might be selected and packed, it has proved extremely deleterious to our fruit export trade, and it seemed worth while to devote part of my research time to the investigation of this important economic question, and accordingly, through the kindness of Mr. Crowe, the head of the Government Cool Stores in Melbourne, a quantity of pitted fruit was obtained, and examined, first histologically, and then physiologically, beginning with the investigation of the enzymes in both sound and diseased specimens. The first results were obtained in September, 1910, and were published up to date in the Journal of the Department of Agriculture of Victoria, December, 1910. The bulk of the field work has been carried out at Burnley Horticultural Gardens, and sincerest thanks are due to the kindness of the Principal, Mr. Pescott, who granted the use of the orchard and supplied me with letters of introduction to some of the leading fruitgrowers in different parts of the States, besides helping in various other ways.

On the 30th of March, 1911, I formulated a theory as to the cause of the disease, and I have been requested to publish this, as it stands, by the members of a commission appointed by the Commonwealth, though it is of necessity still unproved, as the minimum time required for a complete investigation is two seasons. In the event of its being disproved during the coming season the results obtained and put forward in this paper should save any subsequent investigators a great deal of time and labour over unnecessary work. One of the most striking characteristics of this disease is that it may occur in the interior, whilst there are no external indications of its presence. As a rule, however, the external surface of the fruit is marked with distinct depressions of varying sizes, and of a dark green or, more commonly, a brown colour. The pitting is far more pronounced on the calyx end of the fruit, though not always absolutely confined to it.

Examination of the affected areas with a hand lens sometimes shows lenticels situated in them, whilst in other cases no sign of any such structure is apparent. Underneath these groups of surface depressions are found groups of spongy brown cells which adhere to the epidermis when this latter is pulled away from a soft, decayed apple.

As a rule apples which are badly affected with bitter pit become rotten much earlier than the clean ones, and usually the rotting occurs in a peculiar manner, the whole of the flesh becoming converted into a soft brown pulp without any sign of organisms or abrasions on the external surface of the fruit.

Microscopic Structure.

Thin sections through the diseased areas show on microscopic examination that in those pits which are visible on the exterior, the cuticle and epidermic layers, together with from about 8 to 10 layers of the small thick-walled cells immediately underneath the epidermis, do not appear to be affected. The first cells to become metamorphosed are those situated in the vicinity of the transition of the cells possessing small cavities to those possessing relatively much larger ones. The diseased cells appear to be slightly enlarged, irregular in shape, and nearly empty, and are spongy in texture. The cell walls are discontinuous in places, and in the late stages of pitting there is a hollow space in the centre of the area from which all sign of cells has disappeared.

On treatment with aqueous solution of iodine numerous starch grains are disclosed in the region of the cell walls of the affected cells, whereas in the normal flesh when ripe no such starch grains are visible. The majority of my observations and experiments have been made on Anne Elisabeth apples, and specimens of these fruits were obtained from three trees at Burnley at fortnightly intervals. The trees, which are grafted on to Northern Spy stocks, are about 9 years old, and blossomed in 1910 between October 13th and 20th.

On December 12th, though there was no external evidence of bitter pit, in one apple I found just under the surface a few groups of cells which were emptier and very slightly larger than the surrounding cells (see Fig. 1). These were figured and labelled as possibly having some connection with bitter pit. The fruits examined during the next month were quite healthy, but specimens gathered at Burnley on January 9th, 1911, and forwarded to me in Sydney, were found to be badly pitted.

Previous Theories.

The many theories as to the cause of this complaint which have been put forward by various workers are tabulated in a paper written by Mr. Pole Evans,[1] who also enumerates reasons for their rejection. Mr. Evans himself, speaking of South African apples, says he believes the disease is caused by the bursting and consequent breaking down of certain cells of the flesh due to too great internal pressure.

In order to test this theory Prof. Ewart punctured very young apples with the finest sterilised steel needles. When the fruits ripened it was found that in most cases the wound had completely healed, or, as happened in a few instances, there was a surface scar produced which was totally unlike bitter pit. This shows that bursting of the cell wall does not produce this condition. (See Fig. 2.)

History of the trouble.

I cannot find the exact date at which bitter pit was first observed, but it seems to be a comparatively new disease which, in Australia at least, appeared somewhat suddenly about the late eighties or early nineties of last century.

Crichton in the Australian Fruit Culturist,[2] published in Melbourne in 1893, but I suppose written some years previously, does not mention this pitting either as a disease occurring in apples and pears, or in his suggestions regarding the export of fruit. As the common diseases produced by fungi, e.g., Black Spot, Bitter Rot, Mouldy Core, Scabs, etc., are dealt with in his work, as well as canker in pears, and the physiological defect, Water Core in apples, it is inferred that Bitter Pit was not prevalent, or at any rate was not common in Victoria at the time of the compilation of his book, nor could any reference be found to any other disease which might be identical with bitter pit under another name.

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[1] Transvaal Department of Agriculture, Technical Bull. No. 1, July, 1909.

[2] The Australian Fruit Culturist, vol. 2.

Mr. Pole Evans states in his paper[1] on this subject, published in 1909, that from the available literature it is clear that the trouble was known at least 20 years ago in Australia, America and Europe, but the first mention he definitely makes of its being recorded in Australia is the reference[2] to an article published by Mr. N. A. Cobb in the Department of Agriculture, New South Wales, in 1892, in which Mr. Cobb refers the disease to some unknown cause.

Mr. George Quinn, in 1905,[3] remarks that he can cast back an intelligent recollection of South Australian grown apples for upwards of 25 years, but until more than half that period is passed in retrospective vision, no recollection of the defect is forthcoming. According to him, therefore, the disease was first noticed in South Australia within the last 19 years, which again takes us back to the early nineties.

Information regarding this trouble has also been supplied by Mr. D. McAlpine, who says in the Victorian Agricultural Journal, 1902,[4] that many serious complaints have been made during the last few years concerning the occurrence of bitter pit in apples.

Mr. C. French, in the "Destructive Insects of Victoria,"[5] writes that owing to the simultaneous occurrence in Victoria of the disease and the Harlequin fruit bug, Mr. Lidgett, farmer, of the Pentland Hills, of the Bacchus Marsh district, asserted that this insect punctures the fruit, and in this way is responsible for the disease.

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[1] Transvaal Department of Agriculture, Technical Bull. No. 1, July 1909, p. 7.

[2] Ibid, p. 4.

[3] Defects in export apples, Department of Agriculture of South Australia, Bull. No. 7, 1905, p. 9.

[4] Journal of Agriculture, Department of Victoria, 1902, vol. i., p. 804.

[5] Destructive Insects of Victoria, pt. i., 1891, p. 89.

Mr. French states that the insect has been known in Victoria since 1845, and that in former years, though always looked on as a nuisance, they had not given their attention to the destruction of apples till about the time his book was written.

Besides occurring in Australia, bitter pit is common in various parts of the world, and papers dealing with the subject are recorded from America in 1891,[1] and in subsequent years Mr. Pole Evans[2] enumerates the results of observations taken on the disease in South Africa in 1904, and Sorauer,[3] in 1909, describes the trouble as one common in Europe.

Farmer, in 1907, and Massee, in 1906,[4] contribute articles in the Kew Bulletin, in which the latter writes:—"It is perfectly certain that the disease develops during transit in apples coming to England from South Africa, Australia, etc., and the calyx end of the fruit is most seriously injured."

So far as experiments have been made, the nature of the soil or manures do not seem to have a marked effect. The general symptoms suggest the local presence of some substance which kills the cells and prevents the transformation of starch into sugar. These extracts, and, in fact, the whole trend of the modern literature from all parts of the world, seem to show that the trouble is apparently continually on the increase.

History of Spraying Operations.

These somewhat imperfect data regarding the origin of this complaint are now to be followed by data regarding the history of spraying operations, in practice more especially in Australia, for the extinction of fungus and insect pests in orchards.

Crichton,[5] though he, as previously stated, makes no mention of bitter pit, recommends the spraying of apples with solutions of kerosene emulsion, London purple, and Paris green for the extermination of codlin moth, one spraying to be given as soon as a fruit has formed, and a second one two or three weeks later. He also suggests the use of other solutions, such as Bordeaux mixture, etc., as fungicides.

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[1] Jones, L. R., Fifth Ann. Rept. Vermont State Expt. Station, 1891.

[2] Transvaal Department of Agriculture, No. 1, July, 1909, p. 9.

[3] Handbuch der Pflanzen Krankheiten, 1909.

[4] Kew Bull. No. 6, 1906.

[5] Australian Fruit Culturist, Melbourne, 1883, p. 123.

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Valuable information in connection with the introduction of spraying has also been afforded by Mr. C. French in the "Destructive Insects of Victoria."[1] Here he dates the first appearance of the codlin moth in Victoria back for about 35 years. He recommends spraying with London purple and Paris green, as used in America, Europe and elsewhere for the destruction of the pests, the spraying to be done when the fruit is just set.

On page 53 he states further that recent experiments by Prof. Riley in America, and others in Europe, have proved beyond a doubt that Paris green and London purple are the two best materials for spraying yet tried for the purpose.

In Part IV. of the same work Mr. French sets out The Vegetation Diseases Act in Victoria of 1896, the first orchard inspectors being appointed in 1898, from which time, presumably, spraying began to be enforced. Mr. French mentions bitter pit as gazetted under the Vegetation Diseases Act in Pt. IV.,[2] and in this volume he first mentions arsenate of lead as recently coming largely into use in Victoria and other Australian States, with great success in the eradication of codlin moth. Some insight into the increase of spraying operations in Victoria may be obtained from the following extracts from the Journal of the Department of Agriculture of Victoria.

In 1902, page 428, Mr. McAlpine gives the results of successful experiments performed in 1901 and 1902 for the elimination of Black Spot by the use of Bordeaux mixture.

In the same year Mr. Campbell, on page 290, states that the value of spraying for codlin moth is now being recognised, and Paris green applied to the small fruits on which the larvae are crawling about no doubt poisons a number of the latter.

In 1903 Mr. McAlpine describes further spraying experiment for black spot, and on page 354 remarks that spraying for black spot and other fungus diseases has now become a recognised practice in the best orchards.

In December, 1905, on page 737, Mr. J. Laing, Harcourt, states: "For codlin moth spraying with one of the arsenical sprays should be attended to at regular intervals." The same author in October, 1907, remarks that arsenite of lead has been the most successful spray used in the Bendigo and Harcourt districts during the past two seasons.

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[1] Destructive Insects of Victoria, pt. i., 1891, p. 51.

[2] Destructive Insects of Victoria, pt. iv., 1909, p. 25.

In July, 1907, on page 389, Mr. J. G. Turner writes: "The quality of the fruit was, on the whole, far in advance of the previous years; very little was condemned by the inspectors, and in every instance bitter pit was the offending disease."

In December, 1907, Mr. A. A. Hammond, on page 721, advises as follows:—"Spray with arsenate of lead when the fruit sets, and the spraying should be repeated sufficiently often to keep the fruit protected by the mixture whilst it is on the tree. If no rain falls 14 to 21 days may elapse between the sprayings. Spraying need not be done after the 15th March for late fruits, and 14 days before picking for earlier ones."

I have been informed that Mr. Pescott, of Burnley, recommends spraying with arsenate of lead six times during the season.

The Agricultural Journal of the Union of South Africa[1] specifies the year 1892 for the introduction of lead arsenate as a spray for the elimination of codlin moth. From the above it seems to be an indisputable fact that compulsory spraying and the occurrence of bitter pit trouble have apparently simultaneously increased in our orchards. I now proceed to detail the results of my own observations and experiments which have led me to the conclusion that bitter pit is the direct result of spraying the fruits with poisonous liquids.

As the great bulk of material used was obtained from the Burnley Gardens, and as lead arsenate is the spray which is commonly employed there, I have practically confined my attention to the investigation of the effects produced by this material, which is a sparingly soluble compound, and is therefore poisonous,[2] though I do not wish to infer in any way that this is the only spray which would produce the trouble. It is not, consequently, according to Massee,[3] a satisfactory spraying material.

Mr. Pole Evans, in his constantly referred to paper on bitter pit, states that though bitter pit seems to occur in most apple-growing parts of the world, it does not appear to be prevalent in India. Possibly this may have some connection with the following statements:—

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[1] Vol. i., No. 2, March, 1911, p. 249.

[2] Principles of Chemistry, Mendeléef, vol. ii., p. 136.

[3] Diseases of Cultivated Plants and Trees, p. 53.

On page 75 of the Annual Report of the Imperial Department of Agriculture in India for 1904 and 5, in a paragraph dealing with fungus pests, is written: "Spraying, which is in its infancy even amongst the more highly educated farmers of Europe, is not likely to be generally adopted by the ryots for some time to come, and, indeed, the number of diseases that I have seen in India which are likely to repay spraying is small. No special attempts have been made, therefore, to introduce spraying into practice."

In the same volume, p. 91, the following statement occurs: "Every opportunity has been taken of testing remedies which are of use in other parts of the world. This investigation is only possible where injurious insects are met with in sufficient number, and cannot be carried on continuously. The conditions under which agriculture is practised in India differ so much from those of countries where these remedies are discovered, so that any attempt to introduce European and American methods must be preceded by exhaustive trial."

From the above it seems probable that up to the end of the year 1905 at least, spraying was not practised to any extent in India. In none of these reports can I find any reference to the presence of codlin moth, and I have unfortunately been unable to obtain a copy of Mr. Maxwell-Lefroy's Indian Insect Pests, so that I am not able to say to what extent the codlin moth occurs in India.

Mr. Pescott[1] writes: "It is stated that where the codlin moth has obtained a foothold in India it is impossible, owing to climatic influences, to use arsenate of lead, as it burns the trees severely, so chromate of lead is used in its place, reputedly with good results."

This spray was used at Burnley over a limited area of the orchard, but Mr. Pescott says wherever it is sprayed it leaves yellow blotches and spots, otherwise its success as an insecticide is absent.

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[1] Journal of Department of Agriculture of Victoria, vol. ix., pl. iii., March, 1911, p. 206.

Comparison of these two spraying materials, i.e., lead arsenate and lead chromate, shows that the former is sparingly soluble in water, whilst the latter is practically insoluble. As the injurious effect of any poison depends on its solubility in the liquid employed as a solvent, a perfectly insoluble compound, if such exists, in water could not, if applied in water only, do any damage. Both these substances are soluble in dilute vegetable acids, so that if grains of the solid material happen to get into the interior of the apple they might be dissolved by the acid juice. Measurement of the orifice of a stoma shows that six grains of lead arsenate abreast could enter the stomatal orifice.

Comparison of the size of the grains of both materials in their usual commercial forms shows they are very similar in this respect, but probably the majority of the chromate grains are a shade larger than the arsenate ones.

As the disease occurs principally in apples and pears, and as these are the fruits which are particularly liable to be attacked by the codlin moth, it seems to indicate that it is more especially the arsenical sprays which are employed for the destruction of this pest which cause the damage to the fruits.

Close observation of those apple trees at Burnley which were used for my investigations showed that whilst the pitting was practically always confined to the calyx end, it was almost universally more pronounced on that side of the fruit which was not exposed to the sun's rays. (See Figs. 3 and 4.) Also the fruits situated on the southern aspect were more affected than those on the western aspect, whilst those on the northern aspect were the least so. The first fruit to show indications of the disease were those situated within easy reach, and these were, as a rule, much more pitted than those growing above and below them on the tree. All these facts point to spraying as the cause of the trouble, for in the majority of cases the liquid is sprayed straight on to the calyx end of the fruit, and the inference is that those situated within easy reach of the sprayer receive a larger dose. The water containing the spray material soon evaporates from the surface of the fruit, that which rolls down to the more shaded under side, being less quickly evaporated, remains longer, and consequently this side of the fruit would be more likely to become affected.

Most investigators into this problem have agreed that the disease is more prevalent in a wet than a dry season. After spraying there is a deposit of lead arsenate left on the surface of the fruit which remains as a dry powder after the water has evaporated. In wet seasons these particles of powder are continually being dissolved by the rain and carried into the interior of the fruit through the breathing pores, which pores under ordinary circumstances increase the size of their apertures in damp weather.

The present season in Victoria has been an unusually wet one, and as far as I have been able to ascertain, bitter pit has been particularly prevalent.

Whilst conducting my investigations I visited orchards in different parts of the State. Here I learnt that severely pruned trees were apparently more prone to the disease. The effect of this pruning would be to render the fruit more concentrated and more easily reached by the spray. Almost without exception the orchardists volunteered the interesting information that the better the trees are cared for the more subject are their fruits to bitter pit, and that in neglected orchards the trouble is unknown. I personally visited many private gardens and orchards where neither pruning nor spraying is done, and no signs of the defect were noticed, though codlin moth and other troubles were abundant. In Prof. Ewart's private orchard in the Box Hill district 46 trees in one portion of the orchard were sprayed with arsenate of lead just as the petals had fallen, whilst 34 trees, those in the other portion, were left unsprayed. Every apple, either on the trees or in the storeroom from these two parts was examined, with the result that some fruits from almost all the trees in the sprayed portion were pitted, but no sign of a pit could be found on a single apple from the trees in the unsprayed portion. During the previous season no spraying was done, and no bitter pit was noticed on any of the trees, although odd cases might have been present, since no detailed examination of each individual fruit was made, as during the present season.

Time of the Entrance of the Poison.

In some apples such as Anne Elisabeth, Cleopatra and Bismarck, the pitting appears frequently while the fruit is quite immature and unripe, while in other varieties, e.g., Jonathan, it is unusual for it to become apparent till after a varying period of storage. Very frequently no signs of the disease are visible on the surface at all, but nests of diseased cells are present in the interior of the fruit. (See Fig. 5.) These instances appear to indicate that there is more than one period at which the poison may gain access to the interior of the fruit. In cases where the pitting occurs in the quite immature fruit the disease is probably contracted when the fruit is quite young, shortly after flowering. The epidermis from about the central part of the surface of the young fruits belonging to a second crop of a five-crown variety was examined, and it was found that the stomata were open a week after the fall of the petals, and there were 8 to 10 stomata present in one square millimetre of apple surface. (See Fig. 6.) Two to three weeks later no stomata were visible, their apertures being completely closed by growths of new cells. The function of the stomata is taken over by the lenticels, which burst open soon after, and which remain during the life of the fruit, and it seems probable that poisonous material from later sprayings enters through the lenticels, which are almost invariably seen in the locality of the diseased areas in those fruits in which the defect only becomes manifest after storing. (See Fig. 7.)

The poison which enters a stoma or lenticel in solution in water is carried through the intercellular canals, where it penetrates into the interior of one of the cells. All the cells in the young fruit being meristematic are in process of extremely rapid growth, and those cells surrounding that containing the poison divide actively on all sides, and so leave the poison in the interior of the fruit, without any apparent connection with the exterior. All the cells in the flesh of the unripe fruit contain innumerable starch grains, which are continually being hydrolysed into sugars by the action of a diastase enzyme which has been shown to be present in large quantities in the unpollinated receptacles of the apple, as set out in my previous paper[1] on this subject. In the mature cells of the flesh of the ripe apple, no starch grains are visible, having been all converted

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[1] Journal of Department of Agriculture of Victoria, Dec., 1910.

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into the sucroses and invert sugars which characterise the ripe fruit. But the dead cells composing the pitted areas always retain their starch grains, clearly indicating that the diastase is either destroyed or its action inhibited by some means.

In my paper dealing with the enzymes and latent life of resting seeds[1] it may be seen that enzymes are extremely resistant, and something more drastic than the mere bursting of the cells is required to suspend their action.

All these symptoms in addition to the breaking down of the cell walls in the centre of the nests of unhealthy cells could only, to my knowledge, be produced by four agencies acting singly or jointly. (See Fig. 8.)—

1. By bacterial action.
2. By fungal action.
3. By cytase enzymes.
4. By the action of a poison.

The idea of the existence of any living organisms has been almost universally denied by all investigators, and experiments such as I performed at Burnley of trying to infect clean fruit on the trees while still unripe, from pitted fruits, as well as any attempts to produce cultures on gelatine or agar media, to which apple juice had been added, failed to disclose the presence of living organisms of any kind.

As far as is known there are no cytase enzymes present in the apple, and that leaves a poison as the only possible solution of this phenomenon. Investigations on the diastase present in the different stages of the development of the apple were continued, and the results tabulated, as follows:—

Material employed.	Weight of Material.	Reduction to Fehling.
1. Unpollinated receptacles (New York Pippin)	30 grms.	very strong
2. Unripe unpitted flesh (Anne Elizabeth)	20 „	very strong
3. Ripe unpitted apples (Anne Elisabeth)	25 „	strong
4. Pits scraped out from Annie Elisabeth apples	20 „	the merest trace

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[1] Proc. Roy. Soc. London, ser. B., vol. lxxxi, 1909, p. 441.

This series of experiments seems to point out that the first effect of the poison is to inhibit the action of the diastase, which it ultimately kills. The method adopted for the precipitation of the enzymes was essentially the same as was employed in the paper[1] on Enzymes and Latent Life of Seeds.

The consideration into why, in some varieties, the disease is contracted earlier than others, and also why some varieties seem to be much more liable to bitter pit than others is probably connected with the time of opening of the stomata and lenticels, and also with the characteristic textures of the different varieties of fruits. The sappy kinds seem to be more subject to the disease, though it has been observed to be present, more or less, in the majority of the Burnley trees, and as before stated, lead arsenate spraying appears to be particularly vigorous there. Following is a list of trees on which I found diseased specimens in February and March this year at Burnley Gardens:—

Allington Pippin.
Anne Elisabeth.
Bismarck.
Burwood.
Cleopatra.
Cooper's Market.
Dillington Beauty.
Edgar's Red Streak.
Hockett's Sweet.
Jonathan.
Julian.
Laing's Best.
Lord Wolseley.
Newtown Wonder.
Norfolk Bellfing.
Occident.
Ortley.
Prince Alfred.
Purity.
Red Normanby.
Roundaway Magnum Bonum.
Royal Sovereign.
St. Alban's Pippin.
Stark.
Sweet Lading.
Winter Colman.
Crab variety—
Fairy.

Without exception all the orchardists interviewed seemed to consider Munro's favourite as an immune variety, and it was not until the Horticultural Society's Show held last month that I ever saw one of these apples affected in this way. Consequently, though it cannot be considered as exempt, it appears to be very resistant to bitter pit. The water containing the dissolved poison can only enter a stoma or lenticel if the inter-

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[2] Proc. Roy. Soc. London, ser. B., vol. lxxxi., 1909, p. 420.

cellular spaces below these contain liquid and not air. For an air column in a narrow tube forms an efficient barrier to the entrance of a light liquid. The contractions and expansions of the air column due to the periodic temperature variations would cause the liquid which rests over the aperture to be drawn in slightly or forced out, but only extremely small quantities of liquid might eventually gain entrance into the cells from the exterior.

Provided the intercellular canals be full of liquid as would be almost invariably the case in juicy varieties, the poisonous solution would, as before, be drawn into the mouth of the canal, where, by diffusion, some of it would remain in the tube even after the next rise of temperature, and according to the ordinary physical laws of diffusion the dissolved poison would travel down the canal, and would then penetrate into the interior of some cell. According to this theory, therefore, the more juicy fruits ought to be more susceptible to bitter pit than the mealy ones. To test whether this was the case, a series of experiments was performed by which the juice was carefully expressed from equal weights of 3 different varieties of apple, by using moderate pressure.

Variety.	Weight of Material.	Weight of Juice.
Jonathan	20 grms.	7.05 grms.
Anne Elisabeth	20 ,,	7.0 ,,
Munro's Favorite	20 ,,	.4 ,,

The width of the cuticle and the thickness of the cell-walls also vary in these 3 varieties. (See table.) (See figs. 9, 10, 11).

Variety.		First row of cells.		Second row of cells.		Fifth row of cells.		Tenth row of cells.	
	Width of cuticle. mm.	Diameter of cell cavity. mm.	Thickness of cell wall. mm.	Diameter of cell cavity. mm.	Thickness of cell wall. mm.	Diameter of cell cavity. mm.	Thickness of cell wall. mm.	Diameter of cell cavity. mm.	Thickness of cell wall. mm.
Jonathan	.012	.007	.003	.007	.003	.014	.004	.032	.006
Anne Elisabeth	.012	.008	.002	.006	.004	.021	.005	.038	.006
Munro's Favorite	.018	.006	.002	.006	.002	.024	.008	.049	.007

It was found that a disease apparently similar to bitter pit may be produced artificially by means of other poisons. The poisons employed for this were chloroform, corrosive sublimate, and xylol, which are all highly soluble and extremely penetrating, and consequently the appearance was produced very rapidly. In each case a small portion of the surface of the fruit was rubbed with sterilised cotton wool steeped in the liquid, with the following results:—In two days the areas of Anne Elisabeth apples rubbed with chloroform showed distinct pitting. (See fig. 12.) Those (Bethlehemite) rubbed with corrosive sublimate in 24 hours (see fig. 13), and those (5-crown) treated with xylol in 12 hours. (See fig. 14.)

Jonathan apples, whose whole surfaces were washed over with a mixture of new process arsenate of lead, manufactured by the Sherwin-Williams Co. in the proportion of 1 oz. of the solid per gallon of water began to develop bitter pit in about 5 weeks.

In order to ascertain whether any lead arsenate was present in the diseased cells, they were submitted to chemical tests, the experiments being performed in the general laboratory, where no spraying materials were present.

The apples, principally Anne Elisabeth, were well washed in order to remove any traces of spray which might be adherent to the skin. They were then peeled with a clean knife, and afterwards with a clean scalpel the diseased cells were scraped out. These were reduced to ash in a new crucible.

The ash was then tested for the presence of lead, by incineration on charcoal blocks, which were quite new, and the characteristic incrustation of litharge was obtained, and also glassy yellowish beads of lead silicate, but no globules of metallic lead. A further supply of affected cells from Anne Elisabeth apples was prepared in a similar way. They were mixed with sodium carbonate, and left to dry in an oven. In about 8 hours they were converted into a dry, carbonaceous mass which was ignited gently till the flame extinguished itself. The mass was rubbed to a fine powder with a pestle and mortar, when very small glittering metallic globules were discernible with the aid of a hand lens, scattered throughout the powder. Chemical tests were also performed for the detection of arsenic in the scraped out pitted cells, but the characteristic arsenic reactions were not discerned. Possibly this may be due to the quantity of arsenic, if present, being very small, so that the characteristic reaction to Marsh's test is prevented by the large mass of organic matter. In addition any arsenic present would be in the form of an arsenate instead of as an arsenious compound. The former supposition is strengthened by the results obtained by a further experiment, in which small quantities of arsenic trioxide were added to the material, and still the arsenic reaction was not apparent, though larger quantities of this salt added to the material responded to the ordinary arsenic tests. A further possibility is that in the presence of decomposing organic compounds the arsenic of any lead arsenate entering an apple may be slowly evolved in the form of arsenuretted hydrogen.

Conclusion.

The results of my observations, and of the experiments performed, without one single exception so far, seem to indicate that the complaint popularly known as bitter pit is, strictly speaking, not a disease at all, but rather a symptom of slow local poisoning, and that in the cases actually examined so far, it appears to be due to the poisonous compounds sprayed on to the surface of the fruits for the eradication of pests, more especially insect pests.

The poisonous nature of these compounds depends on their relative solubilities in water, and dilute vegetable acids. Theoretically a good spray would be a poison which is insoluble in water, and dilute vegetable acids, but soluble in the digestive juices of the alimentary apparatus of the insect, and it is quite possible that future researches may discover sprays possessing these desired characteristics.

As I am anxious to have this theory proved or disproved as soon as possible, I should like to suggest that fruit-growers in the different States should test it in their own orchards. A good plan would be to leave one central tree unsprayed, and also those forming a kind of circle round it. In this manner the danger of spray material being deposited upon the surface of the fruit on the central tree would be minimised, in an orchard which was otherwise sprayed.

Though, as far as my observations and experiments go, I have limited them to the supposition that the spray passes through the breathing pores of the fruit itself, from the exterior, it is by no means impossible that some of the spray which falls on to the ground, or is washed down by rain, and gradually accumulates in the soil, might enter the plant through the root hairs. That soil is capable of retaining arsenical compounds for a considerable length of time is well known, and when an orchard is sprayed 6 to 16 times in one season, the amount of poisonous spray reaching the soil must become quite appreciable. The sensitive fruit cells would probably be more susceptible to poison than the other parts of the plant since their living protoplasm is reduced to a mere attenuated filament, but this would necessarily be a matter for future investigation.

It might, however, be worth while for orchardists interested in this matter to remove the top 6 inches of the soil from around a tree, which is regularly badly affected with bitter pit, and to replace it with fresh soil mixed with rotted stable manure, to leave the tree unsprayed, and to note whether the pitting were still produced, and if so, to what extent.

In conclusion I take the opportunity of thanking Professor Ewart for the contribution of the results of his own experiments, also for his most valuable advice and assistance. I wish also to thank Mr. O'Brien, assistant in the Botanical Department of the University, for the great help he has afforded in obtaining material, assisting with experiments, taking photographs, etc.

My thanks are due, too, to the following gentlemen, who, in the busiest season of the year, spared some of their valuable time to discuss this matter with me, and afforded useful information :—Mr. Keck, junr., Bendigo, Mr. Somerville, Strathfieldsaye, Mr. Warren, Harcourt, Mr. Warner, Ardmona, Mr. Finlay, Diamond Creek, Mr. C. Lawrey, Diamond Creek, Mr. G. Shepherd, Somerville.

EXPLANATION OF PLATES 1–9.

FIG. 1.

Small portion of the flesh of an Anne Elisabeth apple, gathered December 12th, 1910, stained with watery solution of iodine, and showing a small group of slightly enlarged cells.

FIG. 2.

Photograph of a 5-crown variety of apple, showing the scar produced by piercing with a fine sterilised needle when young.

FIG. 3.

Photographs of 2 Anne Elisabeth apples, showing the pitting on the under, shaded, surface.

FIG. 4.

Photographs of the same 2 apples as in Fig. 3, showing the pitting on the upper exposed surface.

FIG. 5.

Transverse section through a Bismarck apple, showing the pits.

FIG. 6.

Portion of the epidermis from the central part of the surface of a 5-crown apple one week after the falling of the petals, showing a stoma (high power).

FIG. 7.

Piece of epidermis of a ripe apple, showing a lenticel taken from the central part of a pit (high power).

FIG. 8.

Section through the late stage of a pit in an Anne Elisabeth apple.

FIG. 9.

Section of a small portion of the outer surface of a ripe Jonathan apple (high power, drawn to scale.)

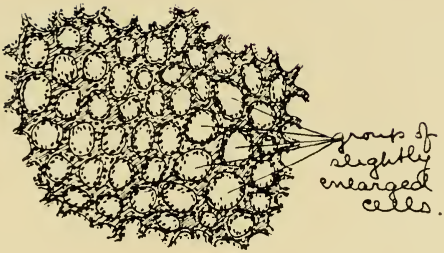


FIG. 1.

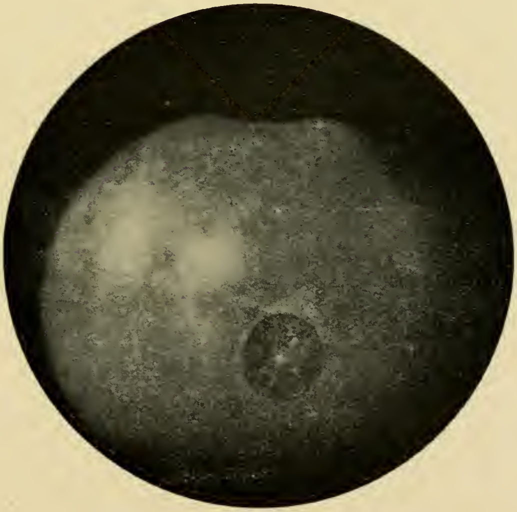
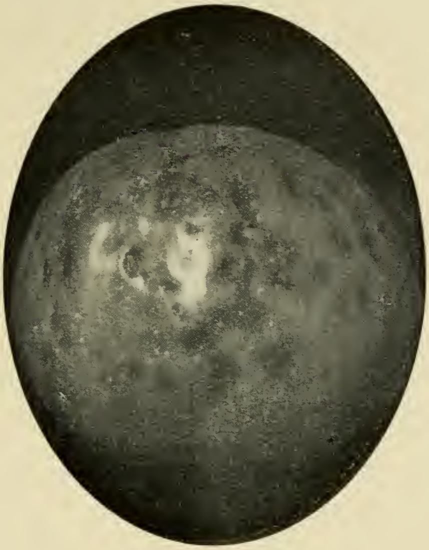


FIG. 2.



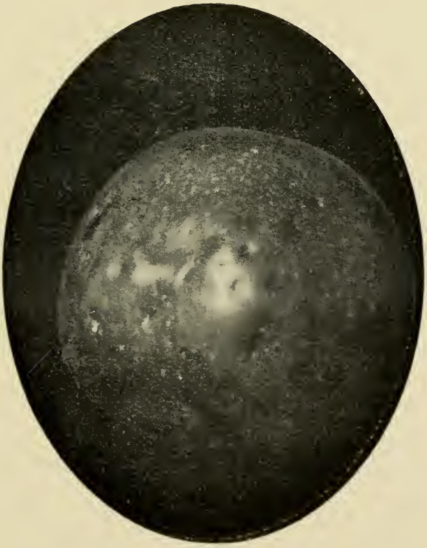


FIG. 3.

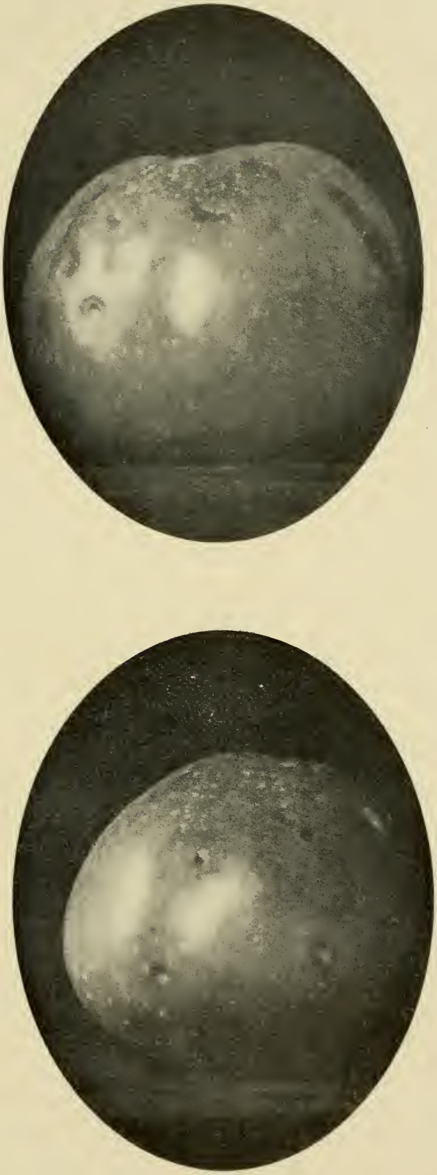
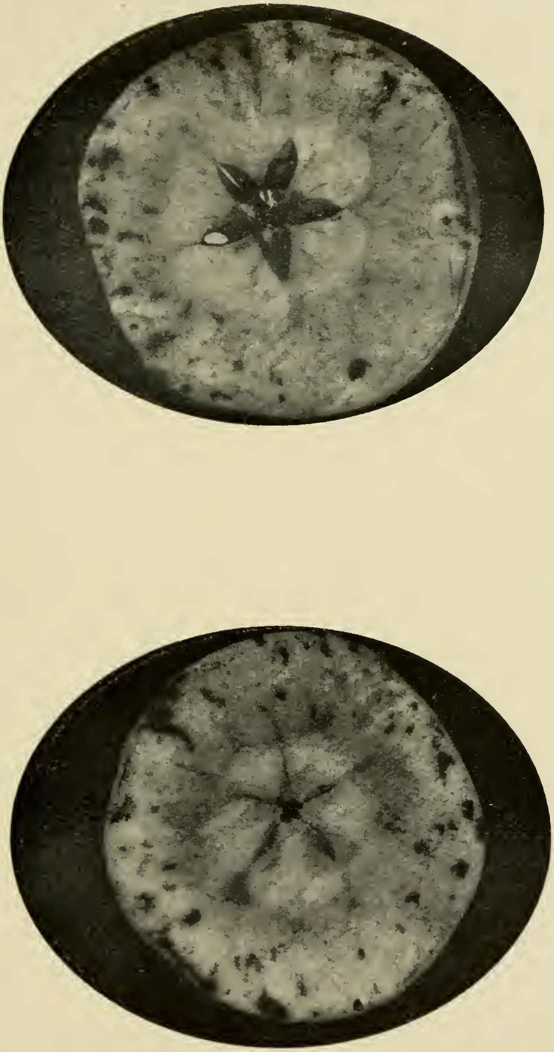


FIG. 4.



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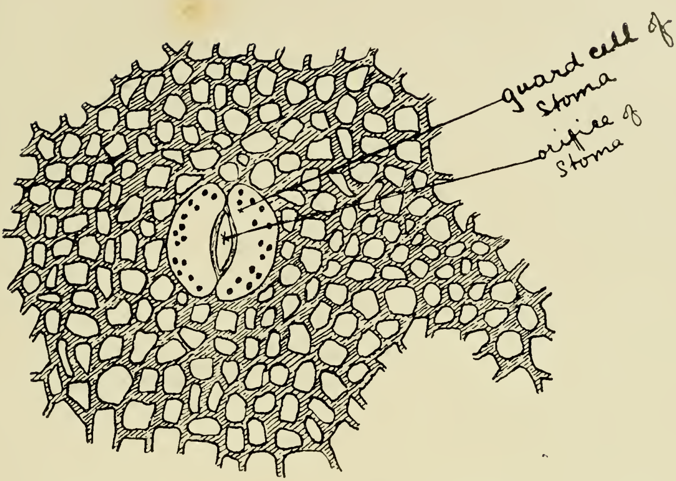

FIG. 6.

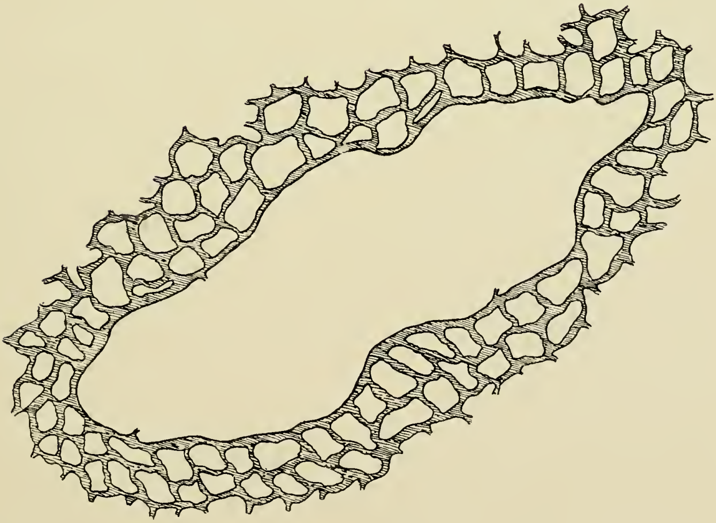

FIG. 7.

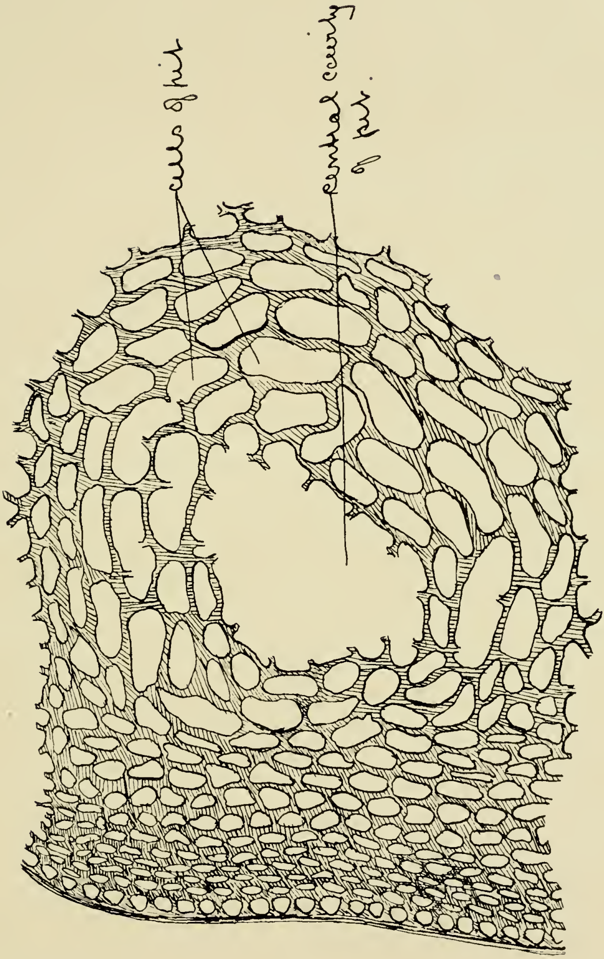

FIG. 8.

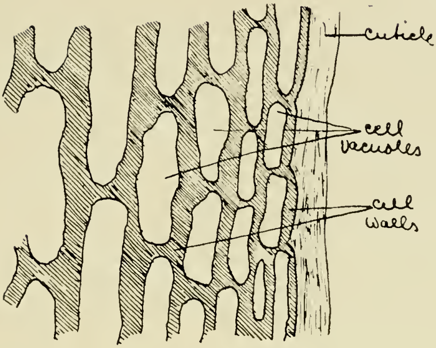

FIG. 9

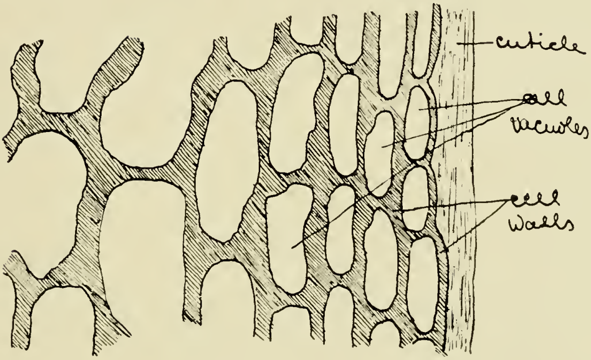

FIG. 10

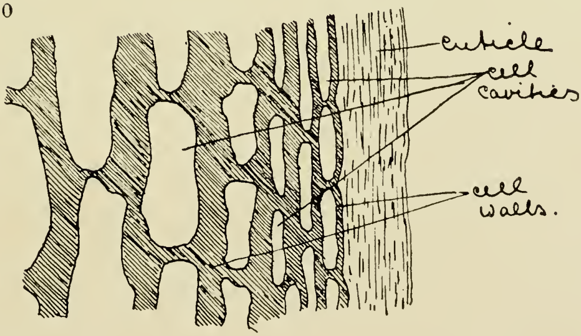

FIG. 11

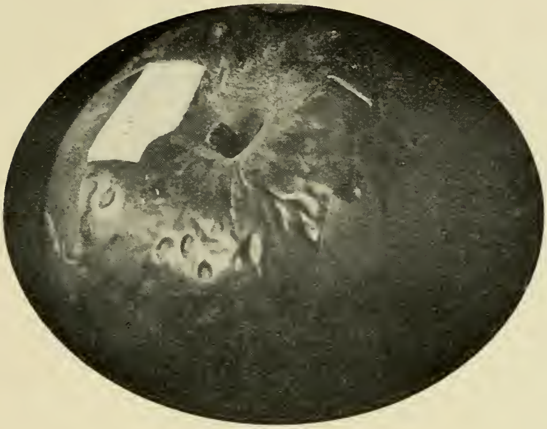

FIG. 12.

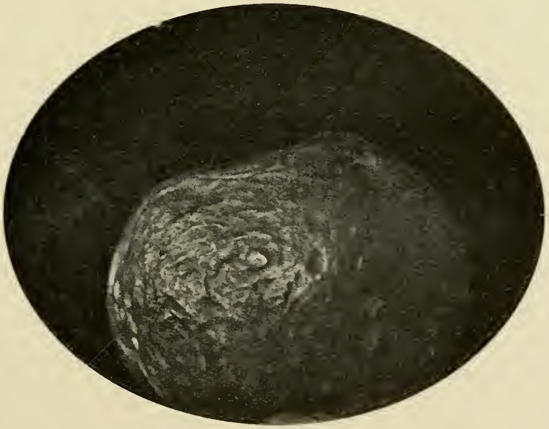

FIG. 14.

FIG. 13

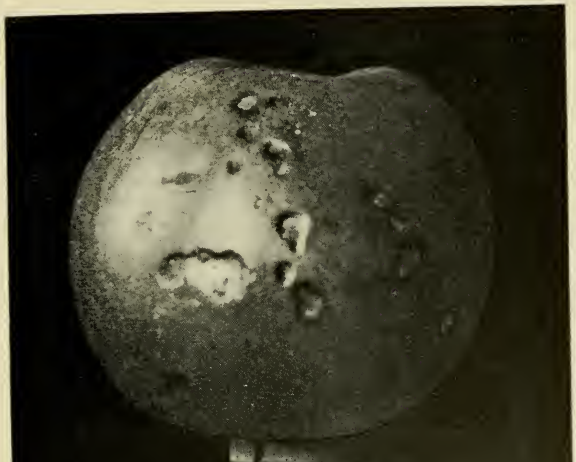

FIG. 15

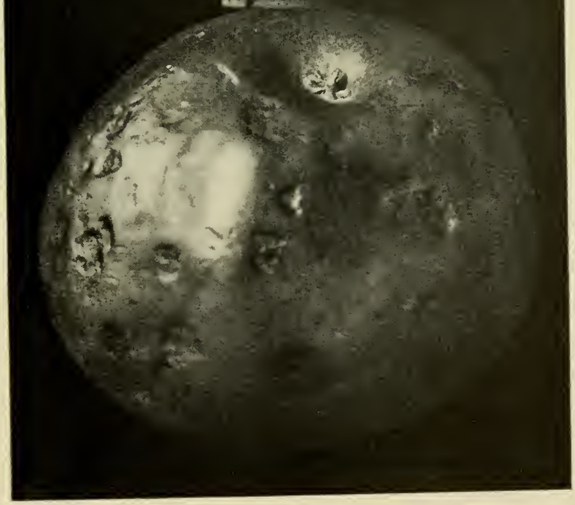

Fig. 10.

A similar section to the above from an Anne Elisabeth variety.

Fig. 11.

A similar section to the above from a Munro's favourite apple.

Fig. 12.

Photograph of an Anne Elisabeth apple, showing part of the surface rubbed with chloroform.

Fig. 13.

Photograph of a Bethlehemite apple, showing part of the surface rubbed with corrosive sublimate.

Fig. 14.

Photograph of an apple, showing part of the surface rubbed with xylol.

Fig. 15.

Photograph of an Anne Elisabeth apple, showing bitter pits on the surface.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. II.—*Papuan Timbers.*

Some of the Properties of Six Species.

By JAMES MANN.

(Government Research Scholar, Engineering School, University of Melbourne.)

(With Plates X.–XX.).

[Read 9th March, 1911].

Introduction.

The investigation of the timber resources of Papua was placed in the hands of Mr. Gilbert Burnett, District Forest Inspector of the State of Queensland, by the Commonwealth Government of Australia, in the year 1908. He reported on 123 species after visiting eight important districts. His report was printed by the Government printer and issued by the Department of External Affairs, Melbourne.

In his report he says:—"The names of the different varieties are such as have been supplied to me by those of the natives of the various localities who appeared to possess the largest amount of knowledge of the native woods; and the greatest care has been exercised in noting them correctly."[1]

Under these conditions, it is highly probable that some confusion may exist, as several names are given to the one variety of tree, these being the names given by the most intelligent natives in the several districts in which the trees grow. Thus, if there are twenty districts, there may be twenty different native names. In a territory such as Papua, where there is no written language and a great number of dialects, it may be necessary to record all names, but if the meaning of each of these words were ascertained and that meaning described the particular genus, some such colloquial name might be adopted.

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[1] Timber Trees of the Territory of Papua: Reports and Catalogue. By Gilbert Burnett.

It is to be regretted that botanical specimens were not procured at the same time, submitted to one of Australia's eminent botanists and placed on record for reference, thus placing in the hands of those seeking reliable information a ready means of identifying the various species in the several districts. Another source of confusion is likely to arise, through the way in which a word describing a tree is spelt. As with children so with most of the island natives the letter R is a great difficulty, and L is nearly always substituted, hence *Aruru* may become *Alulu*, *Araga*, *Alaga*, etc. This has already occurred in two out of the six species which are referred to in the following pages.

The author is not aware that any serious attempt has been made so far to collect and classify the flora of Papua, but it is known that while the great majority of the flora is peculiar to Papua, there are representatives of the mainland also growing there.

In fulfilment of a promise by the Secretary for External Affairs, the author received six species of Papuan woods upon the understanding that they should be submitted to the usual mechanical tests and a report furnished. The colloquial names supplied with the specimens were *Ulabo*, *Alaga*, *Tamonau*, *Kokoila*, *Madave* and *Ilimo*. With the exception of the first two, the spelling used by Mr. Burnett has been adopted. In the case of the two mentioned, it is possible that the spelling of one or other of the authorities may be incorrect, but from the description in the Catalogue, they evidently apply to *Uraba* and *Araga*.

All the specimens were of fair quality, more or less seasoned, and measured nine feet long by six inches wide and four inches deep. With the exception of *Madave* (only one piece being sent), two pieces of each were forwarded. These were cut to lengths of four feet six inches, and subjected to the cross-breaking test, after which they were cut up into specimens for end-grain compression, tension, shearing, bending, charcoal and ash tests. The percentage of moisture in each tested specimen was ascertained, and the change in colour due to heating noted, and also the amount of moisture reabsorbed after drying.

The weights per cubic foot were calculated from the dimensions and weights of the specimens, after they had been planed on an ordinary wood planer. The dry weights were calculated from the moisture percentage experiments. The weight of the seasoned wood was calculated from the observations taken on reabsorption. This weight will vary with the hygroscopic state of the atmosphere.

As this is the first time these timbers have been subjected to mechanical tests, it will be well to treat them rather fully.

Description of the Specimens.

In describing the general appearance of the specimens, the first name will always be that supplied by the Department of External Affairs, and the second the name given to the species by Mr. Burnett.

Ulabo (Afzelia bijuga).—Urabo of the Eastern Division. It is common throughout coastal Papua, and consequently has several different names as follow:—Melila and Mokaika, at Motu; Pida at Vailala; Uio in Western District; Kurabi, North and Eastern Divisions; Bendora, Northern Division.

The specimens received varied slightly in colour, one being fairly dark, somewhat like the dark Tasmanian and Victorian blackwood, but not so rich in colours; heavy, close grained, yellowish brown when freshly planed, but darkening on exposure to the light, of an oily nature, easy to work, and should take a fine polish; if either shavings or sawdust, taken from this wood, be boiled in water for fifteen minutes and the liquid evaporated, a dark shellac-like substance is left, which may be of economic value. Some of the pores contain a yellow sulphur-like material, which came away as fine dust during the cross-breaking tests. Evidently a strong, durable wood; it has been proved to be absolutely proof against white ants, but it will not resist the teredo.

Alaga.—Araga (Fam. Sapotaceae), from the Eastern Division. Being common throughout Coastal Papau, it too has several local names—Ohabu, Vailala; Borua (probably Bolua), Northern Division; Ediua, Kemp Welch; and Koiua, Buna Bay.

The specimens are of a reddish, light brown colour, the sapwood a light bluff. The grain is fairly close and straight. It should be a good wood for joinery and general inside purposes. For boat building, coach and carriage building, it ought to be excellent. It appears to be a fairly durable wood.

Tamonau.—Tamanau (no botanical name) of the Eastern Division; Dandigo, of Buna Bay. Very light medium grained wood, with no particular figure. Light pink or nearly buff in colour, in some lights there is a satin-like sheen and bluish streaks in some of the annual rings. It has not the appearance of a durable timber, being totally unfit for use in damp situations. In one part of the specimen, where it had evidently been on the ground, signs of decay were apparent. It is easy to work, and finishes under the planer with a woolly surface; for light inside work it should be very serviceable.

Kokoila.—Kokoilo (Calophyllum inophyllum) Eastern Division; Oma, Vailala District. Light, cedarlike, open-grained wood, rather a pretty figure (reminding one of cocoanut wood), brownish red in appearance, slightly attacked by a small borer or worm, would not be durable in damp situations, but would be useful for panels as a substitute for cedar. The openness of the grain, either straight from the saw or under the planer, would suggest a great amount of "filling" before polishing, but when properly sandpapered the finish is very fine and the grain seems to be close.

Madave.—Madave, of the Sagarai Valley; "This seems to have affinities with Shorea Dipterocarpeae" (J. H. Maiden). Ome of Vailala. Light, cedar-like, open-grained timber. The colour is a shade lighter than Kokoilo, but the figure is not so pronounced. It is course-grained, easy to work if planed in the direction in which the rings run out, otherwise broad, rough bands are produced. It has the appearance of a brittle timber. It should be useful for joinery where light work is required, especially for cabinet work. It does not give one the impression of being a durable timber in damp places.

Ilimo.—Ilimo, of Motu, (order Bignoniaceae) found in Laloki and Brown River Districts. Iohea, Vailala; Binumba, Cape Nelson and Buna Bay; Kiua, Cape Vogel.

This was the lightest timber received, both in colour and weight, soft, fairly close-grained; when viewed by reflected light on the "quartered" side, it has the appearance of grey satin, on the "backed" side, the appearance is an alternate dark and light grey. Figure somewhat like cedar. It should be a fair wood for light work of any description where it can be kept dry, as it takes up moisture very quickly. After being planed, the surface took on a yellowish green tinge, which nearly disappeared after standing in the air for a few days. It is easily worked on the "backed" side, but on the "quartered" face rough bands appear, as in *Kokoilo* and *Madave.* (See photographs of fractures).

Weight per Cubic Foot and Moisture Percentage.

All timber contains moisture, either as liquid in the cells or moisture in the cell walls. The free liquid drains from the wood in a comparatively short time, reducing the apparent weight as much as twenty-five per cent. in a few weeks, but it takes much longer to evaporate from the cell walls.

Timber is never absolutely dry unless it is submitted to a continuous heat sufficiently intense to drive off all the moisture. The changes which take place in the wood, during this drying process, may be chemical or simply drying due to evaporation; in the same way celluloid, glue and albumen occupy a much larger space when moist than when dry. The three examples quoted illustrate fairly the state of the cell walls before seasoning or drying. Before drying, the cell walls are thick, after they are thin, that is, a circular, oval or polygonal cell wall may be when wet or unseasoned comparatively thick, and the pores or cells comparatively small, but when dry, or nearly dry or seasoned, the cell walls have shrunk and become thinner and the pores larger, but the space occupied by a certain area of the seasoned wood is not so great as that of the unseasoned, otherwise there would be no shrinkage, only loss of weight. Matured wood shrinks much less than semi-matured, and semi-matured less than young saplings. Hence in the wood of a sapling, large checks appear, in semi-matured wood smaller, and in matured wood only small checks are discernible. The various stages can be readily traced in beams cut from different parts of trees, but far more easily from young, semi-matured and matured logs.

In the first case, "heart shake" of a very pronounced character is nearly always developed, in the second case "star," and to a certain extent "cup shake" occurs, but in matured wood the pith has generally begun to decay and the moisture is being evaporated both from the inside and the outside, and if seasoning checks do occur, they are in the form of small cracks, which close up when the process is complete. Also, it is almost a rule that the heavy dense woods contain the least moisture and the more open grained and lighter ones contain the most.

In these experiments, the dry weight of the several species was obtained by weighing one hundred grains of borings, taken from near the fracture, immediately after the specimen had been tested. The borings were then placed in an oven, which was kept for forty-eight hours and upwards, at a temperature of 103 deg. C., kept there in fact until the weight ceased to decrease. The loss of weight was thus directly found, and the percentage of moisture accurately ascertained. Having obtained the percentage of moisture in the timber, and having previously ascertained the weight per cubic foot, it was easy to calculate the "dry weight."

That timber "comes and goes," or expands and shrinks with the weather, can be verified during wet and dry seasons, when many instances come under casual observation; hence the expulsion of moisture decreases the weight of timber, and such weight varies with the proportion of moisture it contains. In the following table (Table 1) the percentage of moisture reabsorbed was ascertained after allowing the dry borings, already mentioned, to stand in the atmosphere for at least seven days. During that time the thermometer never rose above 73 deg. F., but the hygroscopic state of the atmosphere varied. The results prove that timber, air dried, always contains a certain amount of moisture, so that naturally-seasoned timber must always contain moisture, and kiln-dried wood will take up moisture until it reabsorbs within two per cent. of the naturally seasoned wood. The fourth column in the table will therefore give the limit, which the degree of moisture in naturally-seasoned timber of these varieties may be expected to attain in practice.

TABLE 1.

MEAN WEIGHTS PER CUBIC FOOT AND MOISTURE PERCENTAGES.

Name of Timber.	Weight per c. ft. when tested (lbs.)	Moisture p. c.	Weight per c. ft. of dry wood (lbs.)	Percentage of moisture re-absorbed	Weight per c. ft. of seasoned wood (lbs.)
Ulabo	67.47	21.6	42.90	11.00	58.70
Alaga	42.10	16.4	35.20	12.00	39.40
Kokoilo	40.20	13.0	34.97	10.30	38.57
Madave	37.15	14.4	31.80	11.50	35.45
Tamanau	30.40	13.0	26.44	11.00	29.35
Ilimo	30.90	32.8	20.80	11.00	23.08

Change of Colour during Drying.

During the drying operation all the borings changed colour.
Ulabo changed from a yellowish brown to a bluish chocolate.
Alaga, from a pinkish brown to a deeper shade.
Kokoilo, to a purplish brown.
Madave, to a decided brown.
Tamanau, to a light brown: and
Ilimo, to a rather duller grey with a yellowish tinge.

Bending Experiments.

A series of six pieces from each of the varieties was submitted to a severe bending test. The apparatus, designed by the author and used for these tests, is illustrated in Fig. 1, Plate X.

A, is the steaming chamber. B, the boiler. C, condenser. F, funnel for filling the boiler. H, the steam pipe leading to the steam chamber from the boiler. T′, the thermometer to watch the rise of temperature in the chamber. T, the tube around which the specimen is to be bent. W, the weight of ten pounds. P, a pointer, which is attached to the weight at right angles, so that it is always horizontal. J, a jockey clip which is bored for a pin to carry the weight. The clip is attached to a piece of spring brass which rests on the specimen when being bent. S is the specimen, and a is the angle iron under which one end of the specimen is placed. I is the glass front. The whole of the chamber is covered with half-inch felt. The boiler is heated by gas, and the steam in the chamber can be raised to boiling point. By attaching a metal coil to the steam inlet and condenser, the apparatus can be converted into a drying chamber.

The specimens were twenty-two inches long, three-quarters of an inch wide, and three-eighths of an inch deep. A band of spring brass was attached to a brass jockey clip, through which a hole was drilled, so that a brass pin could be inserted in order to carry a casting of lead weighing 10 lbs., to which a horizontal pointer was attached. The specimen was placed under the band, and the whole inserted in the chamber preparatory to steam being turned on. The end opposite to the weight was placed under a piece of angle-iron which is riveted to the end of the steaming chamber. Nine inches from the angle-iron a galvanised iron pipe, two and three-eighths of an inch in diameter, was placed. The specimen rested on the pipe, and the weight was allowed to act during the whole of the steaming process. All the specimens were subjected to the same weight under similar conditions. Each variety of timber was so arranged that two were tested with the annual rings parallel to the direction of bending, two at right angles and two with the rings diagonal. All were placed in the chamber at the temperature of the surrounding atmosphere, which averaged 73 deg. F. The chamber was then closed and steam admitted, and through the plate glass front of the chamber the relative bending of the specimens could be noted from time to time.

Under these conditions, *Ulabo* is undoubtedly the best bending timber, as the whole six bent over the pipe without the least sign of stress on either the compression or tension sides.

Kokoilo came next, with three out of the six bending.

No. 1, being cross-grained, showed a split on the tension side in the direction of the uneven grain. Rings diagonal.

No. 2 was very much stressed and broke with slight pressure. Rings parallel.

No. 3 bent, with slight flaking on tension side. Rings vertical.

No. 4 good bend, but slight twist (twisted grain); no fracture. Rings diagonal.

No. 5 good bend, straight grain. Rings parallel.

No. 6 broke short at the bend. Rings vertical.

Alaga.—All the specimens of Alaga broke, but four of them bent to an angle of 45 deg. before breaking, leaving a fair permanent bend away from the fracture.

Madave.—All the specimens bent to an angle of 30 deg., then broke. Slight permament bend in four of them.

Tamanau.—No. 1, which was a diagonal specimen, bent well, but split on the tension side; the others broke without permanent bend.

Ilimo.—Four of the specimens broke before the steam was applied, the other two took on a permanent "set" of about 15 deg. after remaining without steam for twenty-four hours. In this case the three-quarters by three-eighths pieces were replaced by specimens three-quarters of an inch square, and were steamed for five hours. After steaming for an hour and three-quarters, No. 5, which was a diagonal-ringed piece, broke, No. 6, a similar piece, bent most, the other four remaining at an angle of about 15 deg. With the exception of this set, none of the specimens required steaming for more than fifteen minutes.

Under these severe conditions the six varieties may be classed for bending as follows:—

Ulabo	-	Excellent.
Kokoilo	-	Good.
Alaga	-	Fair.
Madave	-	Moderate.
Tamanau	-	Bad.
Ilimo	-	Bad.

Other Mechanical Tests.

The examination of timbers as to their adaptability for economic purposes requires that they should be submitted to several tests. For instance, timber for engineering purposes should be strong and durable; for architecture it should be strong, durable, comparatively light, with variety in figure, capable of undergoing certain treatment such as bending, polishing and glueing, and of resisting splitting when either nailed or screwed; excessive expansion and contraction during atmospheric changes is very objectionable. For gunstocks, it should be comparatively light, and capable of taking wood or iron screws without tearing; when exposed to wet it should not become rough or woolly, it should clean up well when carved or machined, be close grained and of rather a "cheesy" nature but hard enough to resist ordinary wear and tear without "denting." To a certain extent it should have a good figure, but expansion or contraction is fatal; for most of the minor uses, bending is one of the qualities required.

In investigating the value of the six Papuan species, they have been subjected to the following mechanical tests:—

CROSSBREAKING OR BEAM TESTS.

All beam tests were made on a four foot span, but the effective span was 45.71 inches, due to the method adopted of applying the load. The central load was spread over a width of 2.29 inches by means of two swivel bearings. The span (the supports also being on swivel bearings) was 48 inches.

The formula for calculating the "modulus of rupture" was:—

$$F = 3/2 \times WL'/bd^2$$

Where W = total load required to break the specimen.

L′ = the effective span. (Clear span minus the distance between the centres of the swivel bearings.)

b = the breadth of the test piece.

d = the depth of the test piece.

The "modulus of elasticity" was obtained by plotting, on squared paper (Fig. 2, Plate XI.), the readings taken on a specially designed "Deflectometer,"[1] (Fig. 3, Plate XII.). The formula used for obtaining the "modulus of elasticity" was:—

$$E = WL^3/4bd^3\delta$$

Where W = weight in pounds, producing deflection.

L = clear span (48in.).

b = breadth of the test piece.

d = depth of the test piece.

δ = deflection produced by weight W.

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[1] This instrument was designed by Professor H. Payne, and made by his assistant in the Engineering Labatory. It was used for the first time during these tests, and was accurate throughout.

The following Table 2 gives the mean modulus of rupture and the mean modulus of elasticity of the six species, schedules of details being given subsequently:—

TABLE 2.

Name of Timbers.	F. in lbs per sq. in.	E. in lbs per sq. in.
Ulabo	16485	2084250
Tamanau	8637	1095200
Alaga	8185	1539500
Madave	6605	1081350
Kokoilo	5725	799675
Ilimo	4736	795900

COMPRESSION ALONG THE GRAIN OR COLUMN TESTS.

Specimens, cut from the beam tests, were subjected to compression along the grain tests, that is, as columns. The dimensions were approximately three inches square, the exact figures being given in the schedule of details. The length was twenty inches. The ratio would be nearly 1-7th, consequently they would be short columns, and should give the true compressive resistance of the material in this particular direction.

Strength in compression is a fair gauge of the relative quality of timber for general work, but does not represent its usefulness for special purposes, such as cabinet work, etc.

To ascertain the breaking weight per square inch, the total load producing fracture was divided by the area of the end grain thus W/DB = breaking weight in lbs per square inch, where W = total breaking weight or load.

B = breadth.

D = depth.

The following Table 3 shows the mean strength in compression of the six species:—

TABLE 3.

Name of Timber.	Mean breaking weight in lbs. per sq. inch.
Ulabo	9522
Alaga	6110
Madave	5760
Tamanau	5320
Kokoilo	4795
Ilimo	3550

TENSION TESTS.

Tension tests are not of very great value, as usually timber is stronger in tension than in any other direction, and would seldom fail under that stress while other portions of the same structure, constructed of the same wood and of the same dimensions, were directly under any of the other stresses. In very brittle timber, it might happen, but never in sound, fibrous wood. For comparison, however, it is well that these tests should be made.

The "tension" specimens were prepared in the lathe in the form shown in Fig. 4. The original dimensions were 20 inches long and 2¼ inches square. These were turned to a diameter of ¾ inch in the centre, parallel for eight inches between the shoulders. The portion to be gripped in the testing machine was 3½ inches by 1 3-8th inches diameter, the remainder being just cleaned up. The experiments and remarks are given in the schedule of details. The mean breaking strengths per square inch are given in Table 4.

TABLE 4.

Name of Timber.	Breaking weights.
Ulabo	15750
Alaga	14505
Tamanau	10795
Madave	5380
Ilimo	5300
Kokoilo	4960

SHEARING TESTS.

Specimens cut from the compression pieces were tested in shear. They were approximately three inches square and one and a-half inches deep, the depth being along the grain. They were tested in double shear. Half of the pieces were sheared parallel to the annual rings and the other half at right angles to them. The shearing strength was calculated by dividing the load producing shear by the area sheared. Thus—weight per square inch = Total load/2bd.

Thirty-two shearing tests were made, and the results show that when the plane of shear is parallel to the annual rings, all the fractures are fairly even, and in most cases, the same evenness appears when the plane of shear is at right angles to the rings, but in the case of *Kokoilo* and *Ilimo*, the fractures were very angular, and increased the area of shear from 50 per cent. to 75 per cent.

TABLE 5.

Name of timber.	Mean shearing strength.
Ulabo	2120
Kokoilo	2010
Madave	1810
Alaga	1670
Tamanau	1090
Ilimo	882

From the foregoing tables it will be seen that no definite proportion exists between the stresses of the same timber, but the timbers themselves vary a great deal in strength in their relations to each other. *Ulabo* stands out prominently as the stronger, the sum of the stresses being 43,877 pounds, *Alaga* coming next with 30,460 pounds; then *Tamanau* 25,742 pounds, *Madave* 19,555 pounds, *Kokoilo* 17,490 pounds, and *Ilimo* 14,468 pounds. From these figures it could be reasonably expected that *Ulabo* would be a good engineering timber, *Alaga* and *Tamanau* good woods for joinery and general work, and the remaining three—viz., *Madave*, *Kokoilo* and *Ilimo*—ought to be suitable for light joinery, cabinet work and furniture.

By referring to Table 1 it will also be noticed that the strength does not follow in the order of the weights.

Burning of Splinters.

In addition to the mechanical tests, the colour and quality of the ash produced from the burning of splinters was noted.

When complete combustion takes place, as in the ordinary fire stove or furnace, the ash is generally white or of a dirty greyish colour, while an ordinary wooden match always gives a brittle black ash. If pieces of wood in the form of splinters be taken from the different species, lighted, and allowed to burn in still air, several peculiarities will be observed, which escape observation during ordinary combustion. Some woods burn readily until the whole splinter is consumed; others are difficult to burn; some crackle or splutter, while others burn quietly; again, some glow brightly, others burn dully; one will cease to glow as an ember immediately, another will continue to glow for several seconds, perhaps minutes; one will die out with a brilliant spark and another will die without a glow. The colour of the ash, too, will vary. Some species retain the ash as a short piece of brittle carbon, others retain it as a snow-like point; in others, nothing is left but a most delicate web-like fluff, while others again will leave a feathery substance, which floats away like down. As a means of identification, this property is an aid, and in order to give some idea of its value, is included in these investigations.

The following peculiarities have been noted during experiments on this series of Papuan woods:—

Name of Timber	Remarks on the character of the ash, etc.
Ulabo (*a*) -	Splinter burns fairly well, slowly, leaving a bluish-white ash, which is retained and feathery.
Ulabo (*b*) -	Splinter burns badly, leaving a bluish-white ash, which is retained and feathery.
Ulabo (*c*) -	Splinter burns slowly, leaving a bluish-white ash.
Ulabo (*d*) -	Splinter burns slowly, leaving a bluish-white ash.

[Note.—The spark smoulders for a considerable time; should make a splendid firewood when once lighted.]

Name of Timber	Remarks on the character of the ash, etc.
Alaga (*a*) -	Splinter burns slowly and quietly, leaving a pure white feathery ash.
Alaga (*b*) -	Same as (*a*).
Alaga (*c*) -	Splinter burns with slight "crackles;" white ash
Alaga (*d*) -	Same as (*c*).

[Note.—(*c*) and (*d*) were lighter coloured woods than (*a*) and (*b*).]

Name of Timber	Remarks on the character of the ash, etc.
Tamanau (*a*) -	Splinter burns badly, crackles; white ash, but grey or bluish at the spot where the spark dies.

Tamanau (*b*) - Splinter burns badly, leaving a grey or bluish-white ash.
Tamanau (*c*) - Same as (*b*).
Tamanau (*d*) - Same as (*b*).
Madave (*a*) - Splinter burns slowly, rather badly, bluish-grey ash.
Madave (*b*) - Same as (*a*).
Kokoilo (*a*) - Splinter burns fairly well, leaving a pure white feathery ash, which is retained.
Kokoilo (*b*) - Splinter burns badly, ash as above.
Kokoilo (*c*) - Splinter burns slowly, ash as above.
Kokoilo (*d*) - Splinter burns slowly, ash as above.
Ilimo (*a*) - Splinter burns well, leaving a creamy-white ash, which is retained and feathery.
Ilimo (*b*) - Splinter burns well, but dully, ash as above.
Ilimo (*c*) - Splinter burns well, but quietly, ash as above.
Ilimo (*d*) - Splinter burns well, but quietly, ash as above.

From the above observations, it would appear that all the varieties are fairly rich in potash, but this can only be definitely ascertained by chemical analysis.

Charcoal Properties.

Six cubes of each kind of timber were subjected to a "carbonising process," in order to ascertain their charcoal properties. Each cube was accurately weighed and then placed in an oven, which was surrounded by a bath of ordinary machine oil. The temperature to which the oil could be raised safely had been previously ascertained, and was found to be above 160 deg. C. The cubes were placed in the oven and kept for twenty hours at a temperature of 105 deg. C. The temperature was regulated by means of a "Reichardt's thermo-regulator.' They were again weighed (the percentage of moisture evaporated was calculated), and then immediately placed in a fire clay muffle and packed all round with powdered charcoal. A small hole was bored in the asbestos front, to allow the products of combustion to escape. The closed muffle was then inserted in a gas muffle furnace and the gas turned full on. Carbonisation commenced in five minutes, and the products of combustion ceased to be visible in twenty minutes. The process was complete in forty minutes, when the gas was turned off, and the specimens allowed to cool. They were then removed from the furnace, and again weighed, and the percentage of charcoal ascertained. The following Table 6 shows the total weight of the cubes before being dried, the percentage of moisture evaporated during drying, the weight after being dried, the weight of charcoal produced, and the percentage of charcoal calculated from the dry weight of the wood. All weights are in grains.

TABLE 6.

Name of timber.	Total weight.	Per c. of moisture.	Dry weight.	Wt. Charcoal.	Per c. of Charcoal
Ulabo	825.58	14.87	702.80	237.40	33.77
Alaga	596.00	15.92	501.00	105.60	21.07
Kokolio	482.00	14.73	413.80	115.38	27.88
Madave	433.00	17.34	369.00	88.80	24.06
Tamanau	394.36	13.37	341.60	85.88	25.14
Ilimo	305.00	15.41	258.10	62.65	24.21

This may be considered rapid carbonisation. The temperature was about 700 deg. F.

Percentage of Ash.

The same timbers, in fact, cubes adjoining those treated for charcoal, were prepared in the same manner, and submitted to a similar process, except that the specimens were placed in porcelain crucibles, in an open furnace. The combustion was complete in every case, and the succeeding table gives the amount and percentage of ash obtained:—

TABLE 7.

Name of timber.	Tot. weight wood.	Tot. ash.	Per c. ash.	Colour of ash.
Ulabo	810.36	9.22	1.138	White-yellowish.
Alaga	587.94	5.77	.997	Pure white.
Kokoilo	486.02	2.04	.422	White, dirty.
Madave	427.76	1.37	.319	White yellowish.
Tamanau	392.81	5.15	1.310	White-yellow tinge.
Ilimo	309.54	2.85	.922	Brown mouse colour.

Each set of experiments is given in the schedule of details.

From the above two tables (6 and 7) it will be seen what quantity of charcoal and ash can be obtained from any given weight of dry wood, and also the proportion of volatile matter given off during combustion. It must be remembered, however, that seasoned wood always contains at least 12 per cent. of moisture, so that the volatile matter, apart from the moisture, would be calculated on 88 pounds of dry wood. Take an example, say *Madave*:—100 pounds of ordinary seasoned wood contains 12 pounds of moisture; during carbonisation, this moisture is first driven off, leaving 88 lbs. of dry wood. Now, as *Madave* yields 24 per cent. of charcoal, the weight of charcoal produced from 88 lbs. would be 21 lbs., and the volatile substances would weigh 88—21=67 lbs.

The percentage of ash contained in the charcoal may also be calculated, the results being interesting in that they enable one to select special fuel for special work. In this series, the charcoal of *Tamanau* contains the greatest quantity of ash, and that of *Madave* the least, thus:—

Madave - -	1.3%
Kokoilo - -	1.5
Ulabo - -	3.3
Ilimo - -	3.8
Alaga - -	4.7
Tamanau - -	5.2

With regard to the burning properties of the woods, *Ulabo* proved to be the most difficult to burn, as was anticipated from the experiments on the burning of splinters.

Conclusion.

The author had intended to make several other tests, but considered it unwise to withhold the matter already collected.

Papua contains a great variety of timber trees, the wood from which is of economic value; it is therefore essential that a botanical survey be undertaken and a thorough investigation be entered upon, in order to prove their usefulness for the great variety of purposes to which timber is applied.

The schedules of details and photographs of fractures will help the reader to appreciate the summaries in the earlier pages.

The author desires to acknowledge the kindly help of Prof. Henry Payne and his assistant, Mr. Taylor, also that of Mr. Donald Clark and his assistant, Mr. G. Frieberg, in the charcoal and ash tests.

Schedule of Details.—Beams.

Letter.	Wt. per cu. ft.	Dimensions.			Breaking Weight.	F.	Weight at Elastic Limit.	Defl. at E.L.	E.	Ult. Defln.
		Span.	Breadth.	Depth.						
Ulabo. *Afzelia Bijuga.*										
(*a*)	68.5	45.71	5.86	3.82	21350	17230	12200	.426	2309000	1.05
Good fracture, gave fair warning, fibrous, tough.										
(*b*)	66.4	45.71	5.85	3.65	18300	16070	13600	.65	2035000	1.00
Good general fracture, gave fair warning, fibrous, tough.										
(*c*)	68.8	45.71	3.69	5.87	33400	18010	22000	.402	2097000	0.80
(*d*)	66.2	45.71	3.77	5.90	28000	14630	21500	.405	1896000	0.65
Tamanau. (No botanical name).										
(*a*)	30.7	45.71	5.77	3.83	10200	8260	6100	.429	1213000	1.10
Good general fibrous fracture, gave ample warning.										
(*b*)	30.6	45.71	5.73	3.74	11300	9670	6300	.48	1211000	1.30
Broke suddenly, but good general fracture, fairly fibrous.										
(*c*)	29.6	45.71	3.87	5.67	14100	7770	7300	.293	977100	1.25
(*d*)	30.7	45.71	3.95	5.72	16120	8550	9900	.352	979700	1.20
Broke suddenly, rather brittle.										
Alaga. Fam. *Sapotaceae.*										
(*a*)	42.6	45.71	5.7	3.6	8780	8100	5500	.396	1466000	0.85
Good general fracture, fairly tough, small worm holes in sapwood.										
(*b*)	38.9	45.71	3.75	5.7	16800	9340	11500	.32	1460000	1.45
Good general rather fibrous fracture.										
(*c*)	45.5	45.71	3.70	5.64	17040	9930	9800	.257	1782000	0.95
Distinct compression at 16,800 lbs., good fibrous fracture. *See Photograph, Plate XV.*										
(*d*)	40.4	45.71	5.70	3.75	8500	7270	5500	.349	1450000	0.60
Broke suddenly, brittle fracture.										

Schedule of Details.—Beams.. *Continued.*

Letter.	Wt. per cu. ft.	Dimensions.			Breaking Weight.	F.	Weight at Elastic Limit.	Defl. at E.L.	E.	Ult. Defln.
		Span.	Breadth.	Depth.						
Madave.	*Shorea Dipterocarpeae.*									
(*a*)	36.6	45.71	5.5	3.77	7550	6620	5900	.491	1127700	.70
Broke suddenly, treble scarf fracture, rather brittle.										
(*b*)	37.7	45.71	3.77	5.53	11080	6590	8900	.373	1035000	.65
Broke suddenly, oblique scarf fracture, brittle, some fungus.										
Kokoila.	*Calophyllum inophyllum.*									
(*a*)	41.4	45.71	5.8	3.72	4000	3410	3500	.486	667400	.50
Long scarf fracture, very brittle, cross-grained, some worm holes.										
(*b*)	40.1	45.71	5.9	3.7	8330	7070	3000	.316	878600	.48
(*c*)	40.0	45.71	3.64	5.75	8520	4930	6500	.333	783700	.50
(*d*)	39.3	45.71	3.64	5.74	13100	7490	7000	.324	869000	.65
The latter three broke suddenly, brittle, scarf fractures.										
Ilimo.	Order *Bignoniaceae.*									
(*a*)	31.7	45.71	5.8	3.8	6800	5566	5000	.574	758000	.80
Good general, rather brittle fracture.										
(*b*)	28.9	45.71	5.75	3.85	7260	5255	5300	.53	844500	.95
(*c*)	30.8	45.71	5.80	3.75	4500	3783	3400	.36	853000	.50
Broke suddenly in tension, then sheared.										
(*d*)	32.2	45.71	3.8	5.7	7800	4340	6400	.355	728200	.60
Good general fracture, but brittle.										

DETAILS OF COMPRESSION TESTS.

No.	Length (in.)	Breadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in
Ulabo.						
(*a*)	20	2.90	2.90	8.41	70400	8370
Fracture wedge-shaped, with a tendency to fail in several places ; fibres turned over in the direction of the annual rings.						
(*b*)	14	2.93	2.93	8.58	91300	10640
Fibres turned over in the direction of the annual rings, wedge-shaped fracture on two sides.						
(*c*)	20	2.86	2.86	8.18	71800	8780
Fibres turned over in direction of rings, then sheared.						
(*d*)	20	2.86	2.86	8.18	84300	10300
Same as *(c)*., one side wedge-shaped.						
Tamanau.						
(*a*)	20	2.85	2.85	8.12	42300	5210
Fibres turned over in direction of annual rings.						
(*b*)	20	2.85	2.85	8.12	44000	5420
(*c*)	20	2.85	2.85	8.12	41600	5120
Fibres turned over as above, then the specimen bent as a long column and split down.						
(*d*)	20	2.85	2.85	8.12	44800	5530
Same as c., but bent at right angles to annual rings.						
Alaga.						
(*a*)	20	2.85	2.85	8.12	47000	5780
Fibres crushed at each end, then one end turned over as a long column in the direction of the annual rings.						
(*b*)	20	2.84	2.84	8065	50500	6260
Fibres crushed in the direction of the annual rings.						
(*c*)	20	2.85	2.85	8.12	57500	7080
(*d*)	20	2.82	2.82	7.95	42200	5310
Broke suddenly along seasoning crack, by shear.						
Madave.						
(*a*)	20	2.85	2.85	8.12	46200	5750
Fibres turned over in the direction of the annual rings.						
(*b*)	20	2.83	2.83	8.009	46200	5770
Fibres commenced to turn over, then it sheared suddenly. (See Photograph, Plate 19).						

Kokoilo.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*a*)	20	2.85	2.85	8.12	36300	4470

Fibres commenced to crush, then specimen began to bend until it sheared suddenly.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*b*)	20	2.85	2.85	8.12	39400	4850

First bent considerably as long column, fibres crushed and tension side fractured.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*c*)	20	2.85	2.85	8.12	36200	4410

Fibres first commenced to turn over, then sheared obliquely as in a., but shorter.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*d*)	20	2.85	2.85	8.12	44000	5450

Fibres crushed, then bent as long column

Ilimo.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*a*)	20	3	3	9	30700	3410

Fibres crushed, then broke as long column at right angles to the annual rings.

No.	Length (in.)	Rreadth (in.)	Depth (in.)	Area.	Bk. wt.	Bk. wt. sq. in.
(*b*)	20	2.85	2.85	8.12	27000	3320
(*c*)	20	2.85	2.85	8.12	31000	3820
(*d*)	20	2.85	2.85	8.12	32200	3960

In the last three, the fibres crushed at end in direction of rings.

DETAILS OF TENSION TESTS.

All the tension specimens were 0.76 inch. diam. the area being 0.4536 sq. inches.

Ulabo.

No.	B. wt.	B. wt. sq. in.	Remarks.
(*a*)	9720	21430	Oblique fracture, partial shear, brittle
(*b*)	5000	11020	General fracture, rather brittle
(*c*)	7600	16750	Long scarf fracture
(*d*)	6260	13800	Long scarf fracture

Tamanau.

No.	B. wt.	B. wt. sq. in.	Remarks.
(*a*)	4380	9650	Fairly general fracture, inclined to brittleness
(*b*)	5170	11400	Brittle fracture
(*c*)	5180	11420	Long scarf fracture, partial shear.
(*d*)	4860	10710	Fairly fibrous fracture, partial shear

No.	B. wt.	B. wt. sq. in.	Remarks.
			Alaga.
(*a*)	3820	8420	Scarf, cross-gained fracture.
(*b*)	9300	20500	Good fibrous fracture, straight-grained
(*c*)	10300	22700	Good fibrous fracture, fairly straight grained
(*d*)	2900	6390	Short scarf fracture, cross grained
			Madave.
(*a*)	2530	5580	Scarf fracture, cross grained
(*b*)	2350	5180	Scarf fracture, cross grained
			Kokoilo.
(*a*)	2530	5580	Short brittle fracture
(*b*)	1300	2860	Short brittle fracture
(*c*)	1650	3640	Short brittle fracture
(*d*)	3520	7760	Short brittle fracture, small worm hole
			Ilimo.
(*a*)	2760	6080	Scarf cross grained fracture
(*c*)	2000	4410	Brittle fracture
(*d*)	2500	5570	Brittle fracture

DETAILS OF SHEARING TESTS.

No.	Dimensions. Depth.	B'dth.	Area.	Breaking weight.	B. wt. per sq. in.
			Ulabo.		
(*a*)	1.5	2.9	8.70	25250	2900
(*a*)	,,	,,	,,	16250	1870
(*c*)	,,	,,	,,	29000	3330
		Parallel to rings.			
(*a*)	,,	,,	,,	13000	1490
(*a*)	,,	,,	,,	10000	1150
(*c*)	,,	,,	,,	17500	2000
		Right angles to rings.			

No.	Dimensions.			Breaking weight.	B. wt. per sq. in.
	Depth.	B'dth.	Area.		
			Alaga.		
(*a*)	1.5	2.8	8.40	13000	1550
(*c*)	"	"	"	14100	1860
			Parallel to rings.		
(*b*)	"	"	"	12100	1440
(*c*)	"	"	"	16750	2000
			Right angles to rings.		
			Tamanau.		
(*a*)	1.5	2.9	8.70	13000	1490
(*b*)	"	"	"	6850	787
(*d*)	"	"	"	9600	1100
			Parallel to rings.		
(*a*)	"	"	"	8600	988
(*b*)	"	"	"	11500	1310
(*d*)	"	"	"	7700	885
			Right angles to rings.		
			Madave.		
(*a*)	1.5	2.8	8.4	15250	1820
(*a*)	"	"	"	15250	1820
			Parallel to rings.		
(*a*)	"	"	"	16000	1900
(*a*)	"	"	"	14250	1700
			Right angles to rings.		
			Kokoilo.		
(*b*)	1.5	2.8	8.4	17500	2080
(*c*)	"	"	"	12500	1490
(*d*)	"	2.85	8.55	17200	2000
			Parallel to rings.		
(*b*)	"	2.8	8.4	19000	2260
(*c*)	"	2.85	8.55	18500	2150
(*d*)	"	"	"	17750	2080
			Right angles to rings.		

No.	Dimensions.		Area.	Breaking weight.	B. wt. per sq. in.
	Depth.	B'dth.			
		Ilimo.			
(*b*)	1.5	2.8	8.4	6750	803
(*c*)	,,	,,	,,	6750	803
(*d*)	,,	,,	,,	7000	833
		Parallel to rings.			
(*b*)	,,	2.9	8.70	7750	890
(*c*)	,,	2.85	8.55	8250	965
(*d*)	,,	2.8	8.4	8500	1000
		Right angles to rings.			

NOTE.—All dimensions are in inches, and all weights are in pounds.

DETAILS OF EXPERIMENTS ON THE PERCENTAGE OF ASH.

	No.	Wt. of wood.	Wt. of ash.	Ash per cent.
Ulabo.				
	1	135.93	1.55	1.14
	2	137.00	1.47	1.073
	3	125.02	1.56	1.247
	4	139.52	1.51	1.082
	5	135.63	1.52	1.120
	6	137.26	1.61	1.170
		Mean ash per cent. = 1.1386.		
Alaya.				
	1	97.45	.93	.954
	2	95.90	.90	.938
	3	96.01	.93	.968
	4	95.31	.87	.912
	5	96.34	1.13	1.172
	6	96.93	1.01	1.041
		Mean ash per cent. = .9975.		
Ilimo.				
	1	51.93	.57	1.111
	2	49.30	.42	.851
	3	50.60	.50	.988
	4	51.38	.44	.856
	5	57.17	.51	.892
	6	49.16	.41	.834
		Mean ash per cent. = .922.		

No.		Wt. of wood.		Wt. of ash.		Ash per cent.
Madave.						
1	-	71.07	-	.22	-	.309
2	-	71.30	-	.23	-	.322
3	-	73.43	-	.23	-	.313
4	-	73.72	-	.25	-	.339
5	-	68.36	-	.22	-	.321
6	-	69.88	-	.22	-	.314
		Mean ash per cent. = .3198.				
Kokoilo.						
1	-	86.14	-	.31	-	.358
2	-	83.48	-	.32	-	.385
3	-	86.24	-	.34	-	.394
4	-	80.77	-	.31	-	.383
5	-	70.65	-	.35	-	.495
6	-	78.74	-	.41	-	.520
		Mean ash per cent. = .442.				
Tamanau.						
1	-	66.38	-	.90	-	1.355
2	-	64.70	-	.84	-	1.298
3	-	65.34	-	.88	-	1.346
4	-	65.02	-	.84	-	1.290
5	-	65.15	-	.81	-	1.243
6	-	66.22	-	.88	-	1.329
		Mean ash per cent. = 1.310.				

APPENDIX, 26TH JUNE, 1911.

Subsequently to the paper being read, the calorific power of the charcoal was ascertained. The experiments were carried out with the latest form of the "Berthelot-Mahler-Krocker Bomb Calorimeter," the formula used being that supplied with the apparatus. The equivalent of the calorimeter was first ascertained by burning known weights of naphthalene, and the constant thus obtained was used throughout the experiments.

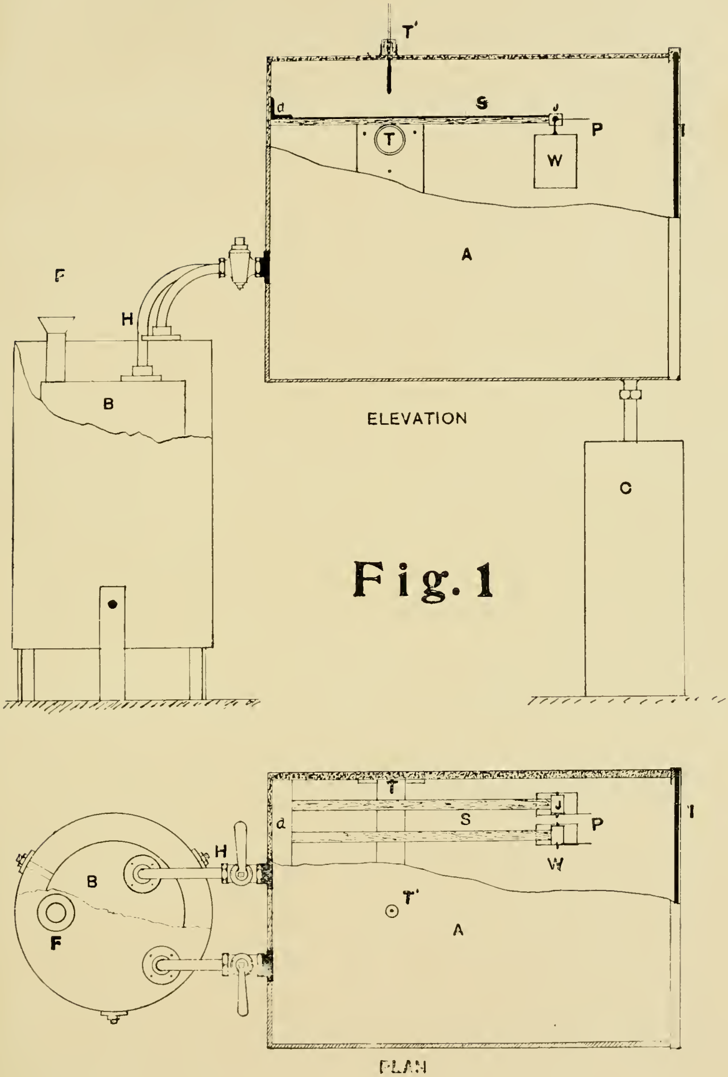


Fig. 1

Fig. 2

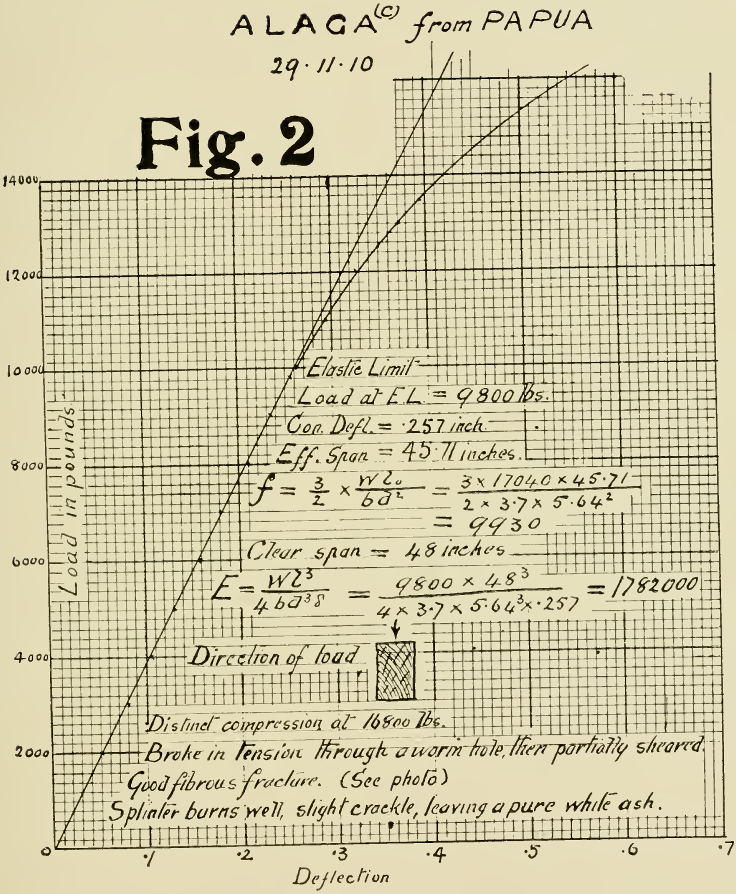
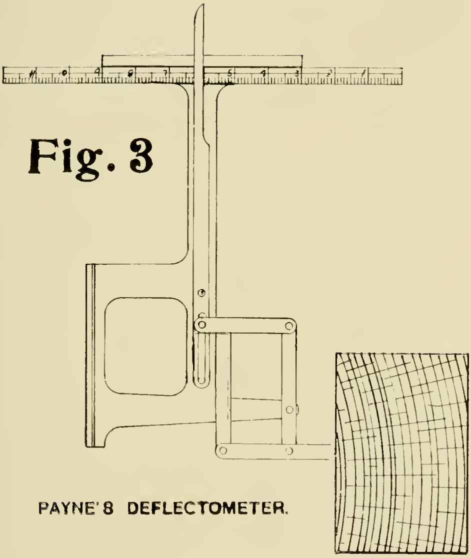

ALAGA(c) from PAPUA
29·11·10
Elastic Limit
Load at E.L. = 9800 lbs.
Con. Defl. = ·257 inch.
Eff. Span = 45·71 inches.
f = 3/2 × Wl₀/bd² = (3 × 17040 × 45·71)/(2 × 3·7 × 5·64²) = 9930
Clear span = 48 inches
E = Wl³/4bd³δ = (9800 × 48³)/(4 × 3·7 × 5·64³ × ·257) = 1782000
Direction of load
Distinct compression at 16800 lbs.
Broke in Tension through a worm hole, then partially sheared.
Good fibrous fracture. (See photo)
Splinter burns well, slight crackle, leaving a pure white ash.
Load in pounds
14000
12000
10000
8000
6000
4000
2000
0
·1
·2
·3
·4
·5
·6
·7
Deflection

Fig. 3



PAYNE'S DEFLECTOMETER.

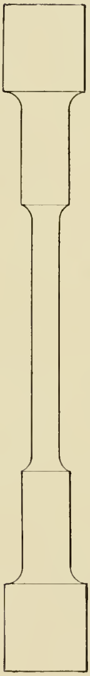
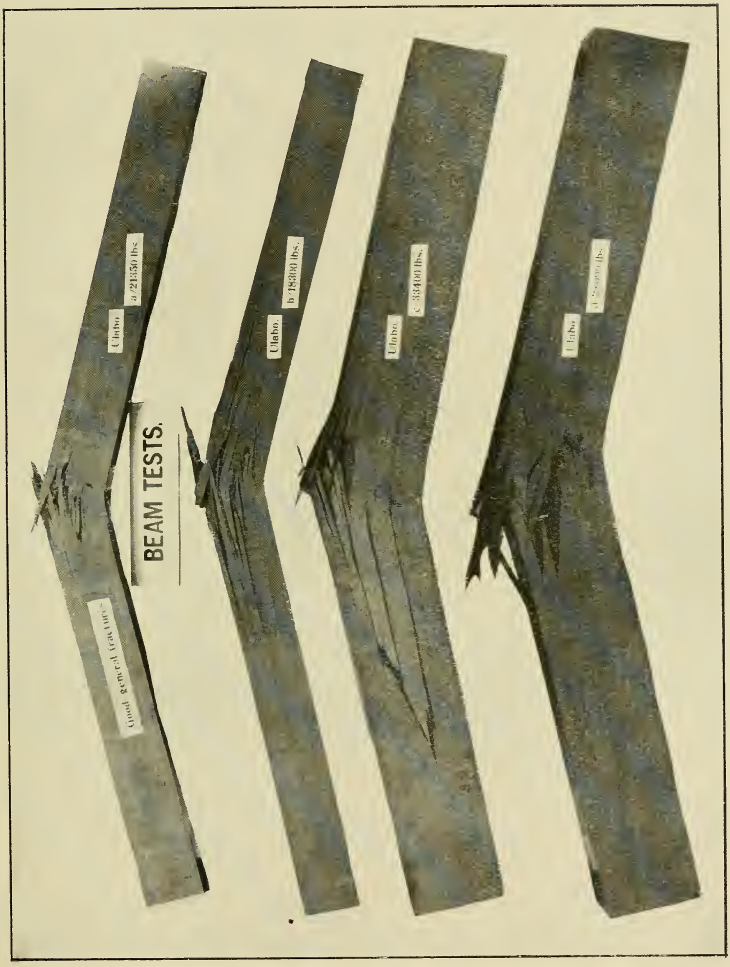
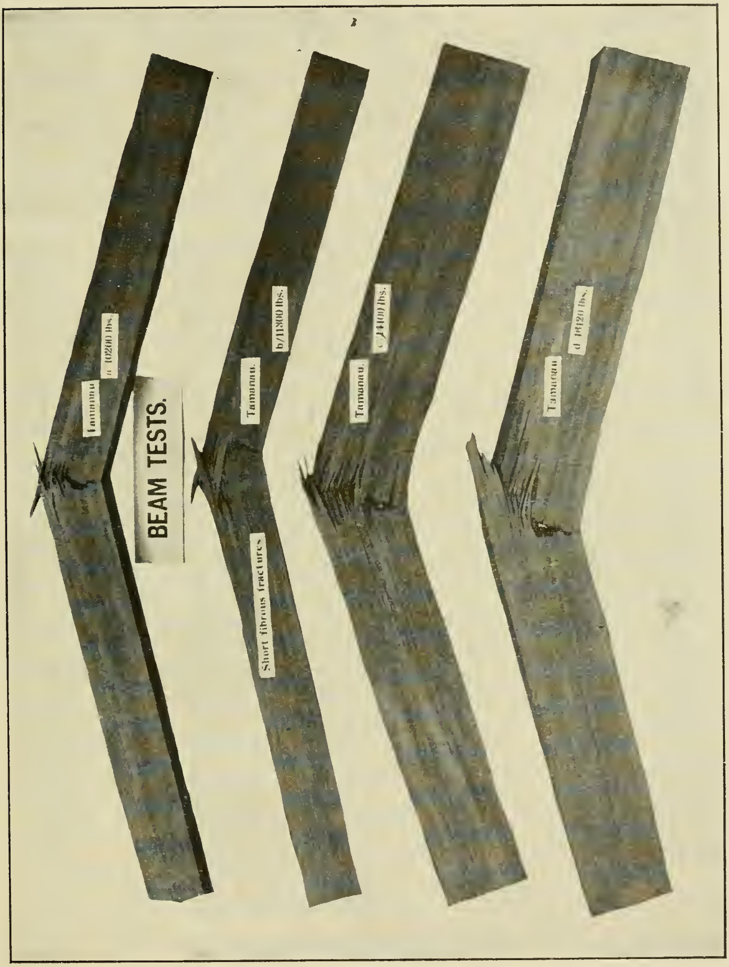
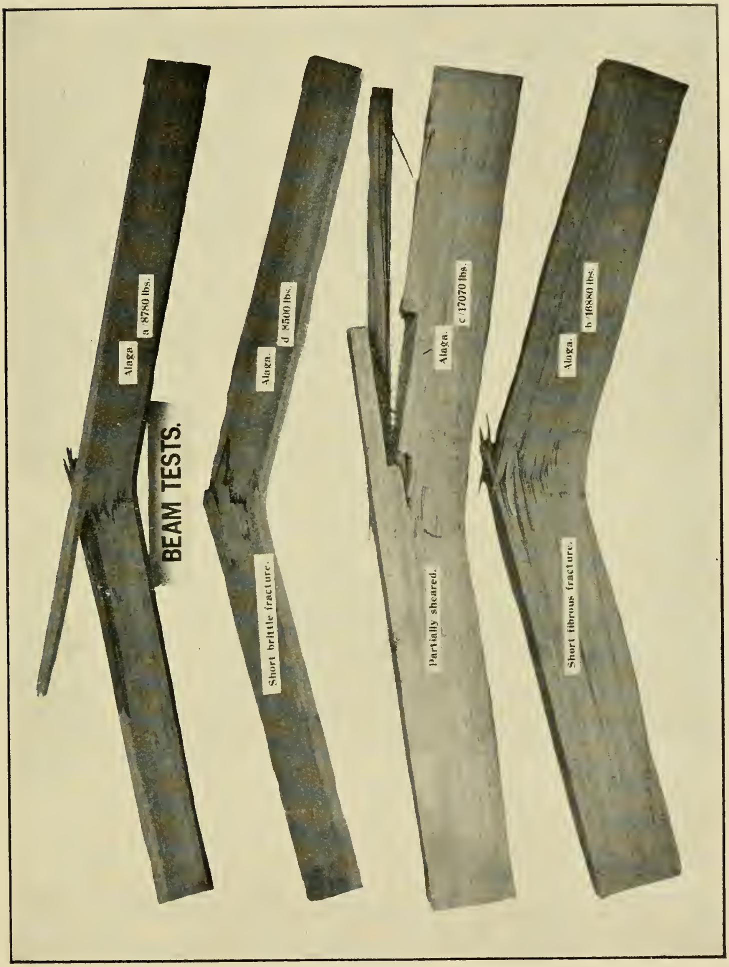


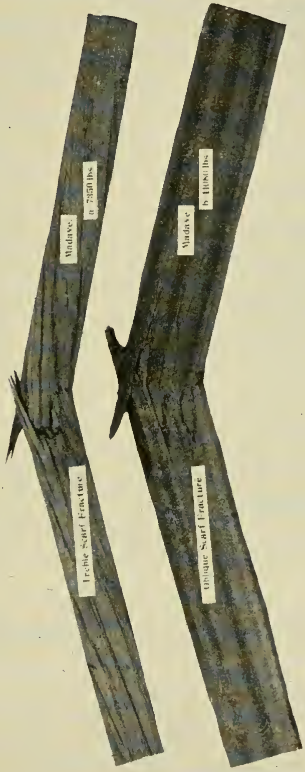
Fig. 4

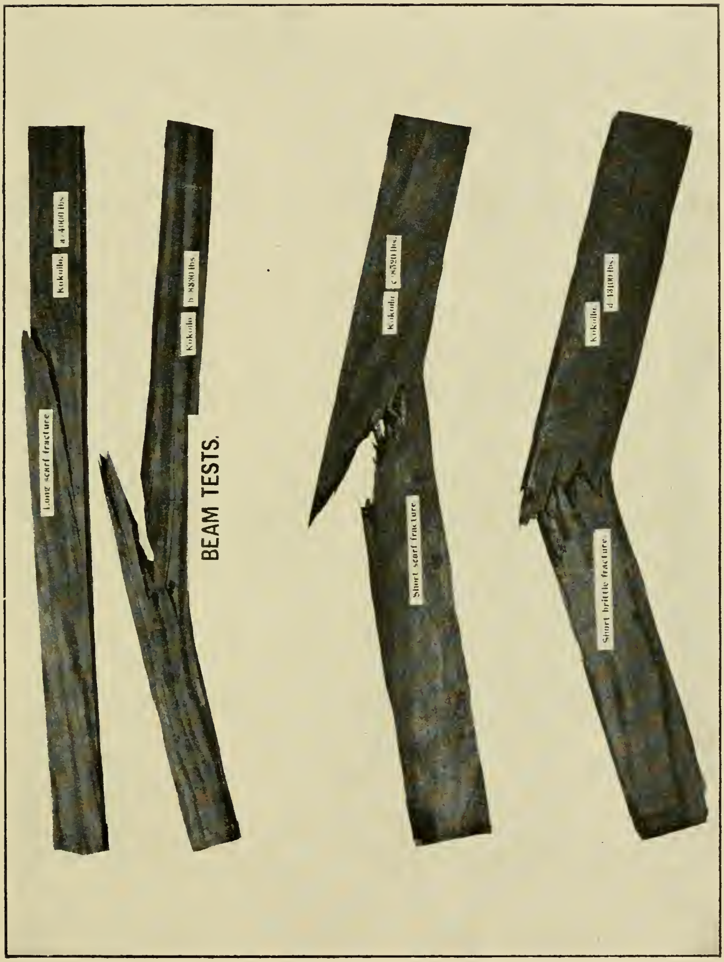

BEAM TESTS.
Ulabo.
a /21350 lbs.
Good general fractures
Ulabo.
b /18300 lbs.
Ulabo.
c 33400 lbs.
Ulabo.

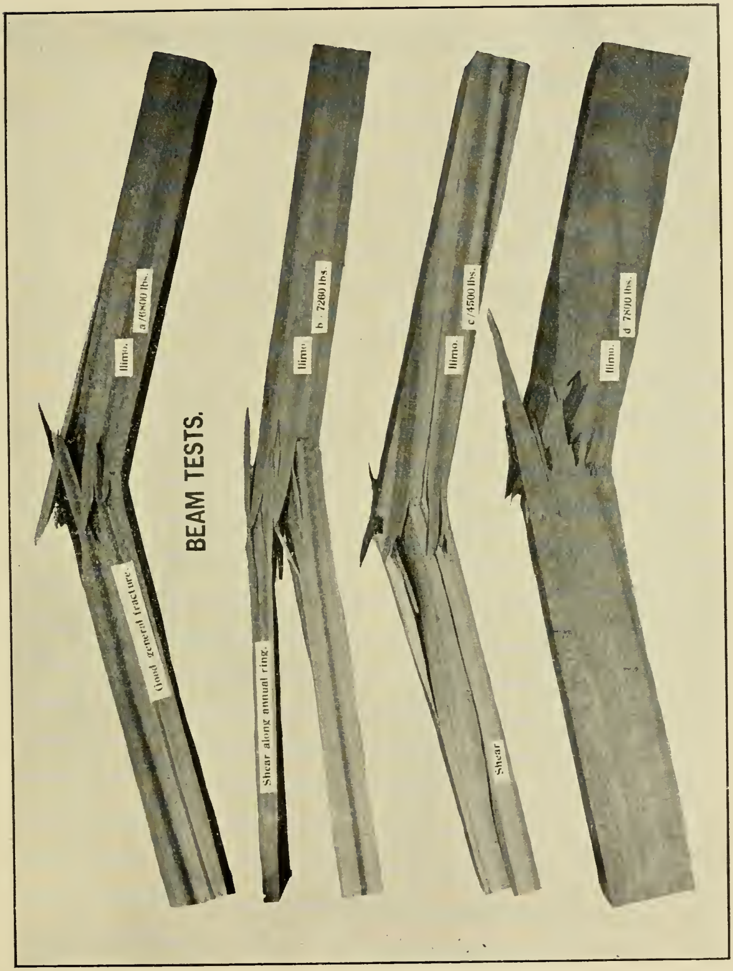

Tamanu
a 10200 lbs.
BEAM TESTS.
Tamanu.
b/11800 lbs.
Short fibrous fractures
Tamanu.
c/14100 lbs.
Tamanu
d 18120 lbs.


BEAM TESTS.
Alaga
a 8780 lbs.
Alaga.
d 8500 lbs.
Short brittle fracture.
Alaga.
c 17070 lbs.
Partially sheared.
Alaga.
b 16880 lbs.
Short fibrous fracture.

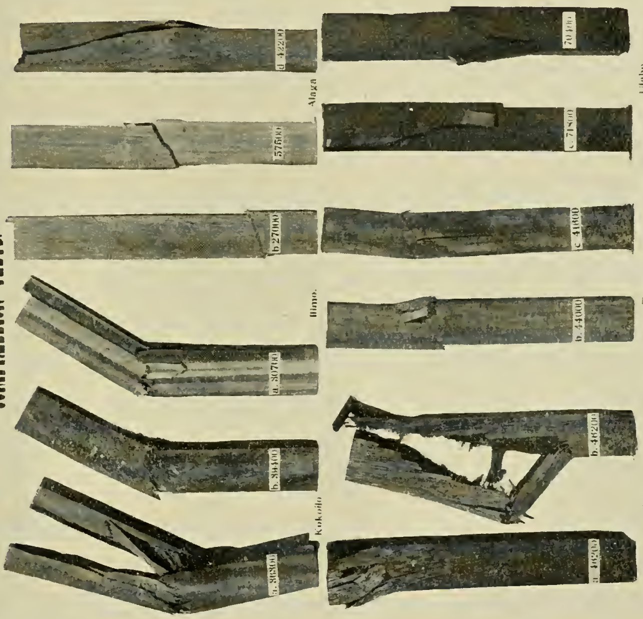
BEAM TESTS.

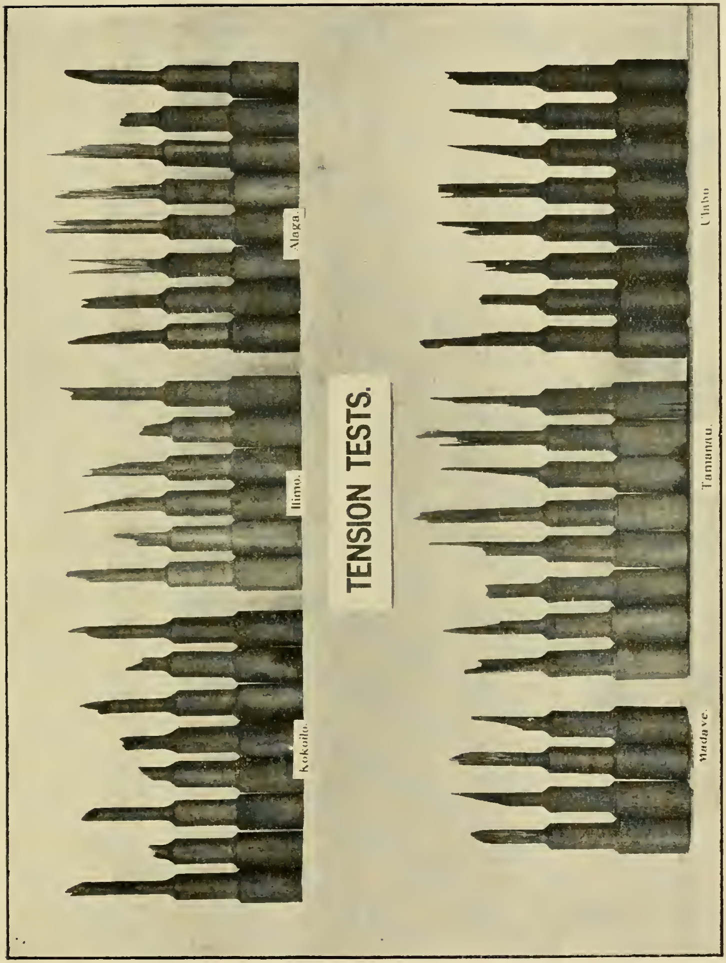

Madave
a 7350 lbs
Treble Scarf Fracture
Madave
b 11080 lbs
Oblique Scarf Fracture


BEAM TESTS.
Kokodo. a 4000 lbs
Long scarf fracture
Kokodo b 8890 lbs
Kokodo c 8520 lbs.
Short scarf fracture
Kokodo d 13100 lbs.
Short brittle fracture


BEAM TESTS.
Ilimo.
a/6800 lbs.
Good general fracture.
Ilimo.
b/7280 lbs.
Shear along annual ring.
Ilimo.
c/4500 lbs.
Shear
Ilimo.
d 7800 lbs.

COMPRESSION TESTS.




TENSION TESTS.
Alaga.
Ilimo.
Kokoilo.
Uhiu
Tamanau.
Madave.

By comparing the summary of ash test with the calorific powers of the charcoals, it will be seen that those woods leaving the least ash produce the greatest amount of heat, thus :—

Name of timber.		Percentage of ash from wood.		Calorific power from charcoal.
Madave	-	1.3 per cent.	-	7870 calories
Kokoilo	-	1.5 ,,	-	7779 ,,
Ulabo	-	3.3 ,,	-	7516 ,,
Ilimo	-	3.8 ,,	-	7456 ,,
Alaga	-	4.7 ,,	-	7288 ,,
Tamanu	-	5.2 ,,	-	7155 ,,

EXPLANATION OF PLATES.

PLATE X.

Fig. 1.—Experimental apparatus for bending wood.

PLATE XI.

Fig. 2.—Graph showing deflection under cross-bending tests.

PLATE XII.

Fig. 3.—Deflectometer designed by Prof. H. Payne.
Fig. 4.—Form of tension specimen for wood.

PLATE XIII.

Photographs illustrating fractures under Beam tests.—Ulabo.

PLATE XIV.

The same.—Tamanau.

PLATE XV.

The same.—Alaga.

PLATE XVI.

The same.—Madave.

PLATE XVII.

The same.—Kokoilo.

PLATE XVIII.

The same.—Ilimo.

PLATE XVIX.

Photograph illustrating compression tests.

PLATE XX.

Photograph illustrating tension tests.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art III.—*A List of Victorian Rotifers, with Description of Two New Species and the Males of Two Species.*

By J. SHEPHARD.

(With Plates XXI.-XXII.).

[Read 20th April, 1911.]

In 1891, under the title of "Notes on Victorian Rotifers,"[1] Mr. H. H. Anderson and myself gave a list of species of *Rotifera* identified up to that date, including several forms described as new. Since that time no further enumeration has been published, although several new species have been recorded. An extended list was submitted by myself at the last Melbourne meeting of the Australasian Association for the Advancement of Science, and occupied the attention of the biological section for a few minutes, but it was not published, and therefore remained unavailable to students of this class. Having in the course of intermittent observations added considerably to the original list, it appears desirable to publish a fresh enumeration, more particularly as it can be supplemented by the inclusion of two new species of *Brachionus*, and the description of the males of two species of *Lacinularia*. As much of the literature of the subject is unprocurable here, I have availed myself of the kind services of Mr. Rousselet, the well-known authority on the class, and submitted to him copies of my drawings of the two unidentifiable forms. and his opinion is that they are certainly new. For the advantage of having all the known Rotifers of Victoria in one record, those mentioned previously are included, but are merely named. an asterisk being used to indicate them, excepting in a few cases where some further remark seemed advisable. The full list now given, as students of the group will know, only partially represents the forms existing in Victoria. Some sustained work would speedily double or treble the total number.

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[1] Proc. Roy. Soc. Vict., vol. iv., 1892, pp. 69-80.

Among the species described from Australian forms are some very interesting animals which have a bearing on the question of geographical distribution. Generally the distribution of these animals is regarded as world-wide, and recent discoveries tend to support that opinion. Two of the Australian species have lately turned up, one, *Lacinularia elongata*, near Paris, and the other, *L. elliptica*, in South Africa. There are, however, three species of this genus still unrecorded elsewhere, and it is remarkable that they are strikingly conspicuous forms occurring frequently and in great profusion. A consideration of these forms and their occurrence certainly suggests their adaptation to conditions of frequently recurring periods of drought, combined with wet intervals, when the power of rapid multiplication becomes a favouring factor. With fuller knowledge of this portion of our fauna this indication of distinctiveness may increase, and the thought of such a possibility certainly gives zest to the work of investigation.

The author is responsible for the identifications, excepting a number kindly supplied by Mr. W. Stickland, whose name is appended in each case.

Order I.—RHIZOTA.

Family 1.—FLOSCULARIADAE.

Floscularia.

**F. coronetta.*

F. coronetta, var. Hudson (The Rotifera, Supp., p. 61), syn. *F. tenuilobata*, Anderson (Jour. Asiatic Soc. Bengal, vol. lviii., No. 4, 1889, p. 346).

Mr. Rousselet considers *F. tenuilobata* identical with *F. coronetta* (Jour. Roy. Micro. Soc., vol. xiii., 1893, p. 451). Comparison of the figures of these two forms shows that the difference between them exists chiefly in the form of the knobs at the ends of the lobes of the corona, and that there is agreement in regard to the lobes being of equal thickness down to their bases, instead of widening as in Hudson's figure of *F. coronetta*. The two are much closer in agreement with each other than either of them is with *F. coronetta*. Adopting Rousselet's decision to reject Anderson's species as distinct from *F. coronetta*, it appears best to regard it as in agreement with Hudson's variety. Dr. Hudson gives a figure supplied by Mr. Burne Poole, of Adelaide, and this is in close agreement with Victorian specimens, of which a considerable number have been seen.

Treasury Gardens, Melbourne; Heidelberg and Cheltenham.

**F. cornuta.*

**F. campanulata.*

**F. ornata.*

F. trilobata, Collins. Cheltenham.

**F. evansoni.*

**F. ambigua.*

Stephanoceros.

S. eichornii, Ehrenberg.

Botanical Gardens, Melbourne, and lagoons along the Yarra valley.

Family 2.—MELICERTADAE.

Melicerta.

**M. ringens.*

**M. conifera.*

M. fimbriata (Shephard and Stickland. Victorian Nat., vol. xvi., No. 3, p. 38).

Mr. Rousselet in his "Third List of New Rotifers since 1889" (Jour. Roy. Micr. Soc., 1902, pp. 149), queries this as synonymous with *M. tubicolaria*, Ehrenberg. Regarding this opinion it may be pointed out that the distinction chiefly rests on the observed habit of *M. fimbriata* of forming a long filament by means of the organ which in *M. ringens* serves to form a spherical pellet, and in *M. conifera* to produce a conical one. The ventral antennae of *M. fimbriata* are also shorter. The specific characters of *M. tubicolaria*, as given by Hudson and Gosse, are, "Lobes when extended more than three times the width of the body; antennae very long; tube a gelatinous sheath without pellets." *M. fimbriata* differs in regard to the last two of these characters. *M. tubicolaria* has been known since 1838, and appears to have been closely studied by a number of observers, yet no mention can be found of filaments or pellets being formed by it. Had such an observation been recorded the chief specific character would disappear. *M. fimbriata* undoubtedly uses the ciliated cup to form filaments. It is, of course, possible that the European form may be found to possess this power, but until this is done it appears best to retain the form as a true species.

Limnias.

**L. ceratophylli.*
**L. annulatus.*
**L. granulosus.*
L. shiawasseensis, Kellicott. Botanical Gardens, Melbourne.

Cephalosiphon.

**C. limnias.*

Oecistes.

**O. crystallinus.*
**O. intermedius.*
**O. intermedius*, var.
O. longicornis, Davis. Common.
O. pilula, Wills. Cheltenham.
O. brachiatus, Hudson. Cheltenham.
**O. wilsoni.*

Lacinularia.

**L. socialis.*
**L. pedunculata.*
L. striolata, Shephard. Brighton and Caulfield.
L reticulata, Anderson and Shephard. Proc. Roy. Soc. Vict., vol. iv., N.S., 1892, p. 73.

The original description of this form contains the statement that it is "found in small colonies."

It has since been found in clusters of quite remarkable size lying on the surface of the mud in a shallow pool in lobose masses upwards of an inch in diameter. These large colonies are masses of adherent dense, gelatinous tubes, and are due to that habit of the young, unlike those of *L. striolata* and *L. pedunculata*, of joining the colony from whence they are hatched out. The specimens from which the species was first described were in an early stage, the form being prevalent in pools which entirely dry up in summer; small clusters are formed by individuals hatched from resting eggs coming together, and these, under favourable conditions, growing to the dimensions mentioned. At this early stage the colonies are swimming freely, coming to rest later.

A number of free swimming forms were found about and among the females which compose the large aggregations, and their movements left little doubt that they were the males of the species. As will be seen from the figure (Plate XXI., fig. 1) the male animal is elongated and vermiform, with a conical corona and terminal foot. It possesses two red eyes placed well forward, a small dorsal antenna, and a ciliated pit over the foot. The greater part of the interior is occupied by the sperm sac. No traces of an alimentary system were visible. The length was 0.24 mm.; depth, 0.05 mm.

L. elongata, Shephard. It is noteworthy that this species was found near Paris in large numbers in 1909. Some specimens supplied by Mr. Rousselet agree perfectly with the Victorian form.

The species is common along the valley of the Yarra.

L. natans, Western. Very common.

L. elliptica, Shephard. Found in many localities in large numbers, often in company with *L. natans.*

The male of this species was discovered when a very plentiful gathering was under examination. An examination of the figure (Plate XXI., fig. 2) shows a very remarkable form, differing markedly from every other described male of the genus *Lacinularia*, the contrast with the male of *L. natans* being particularly strong, although the females resemble each other so closely as to need careful observation to be distinguished. The animal is of elongated form, the corona being of conical shape with a blind cavity representing the buccal opening of the female. There is a prominent dorsal antenna connected by a nerve thread with a large mass lying immediately behind the corona. About two-thirds of the whole length from the anterior, and dorsally placed, is a ciliated pit with a cluster of glands accompanying it. The posterior end terminates in an acute cone thickly furnished with cilia. The anterior portion of the body is occupied with a sac filled with spermatozoa. There are two red eye spots placed well forward. Total length, 0.21 mm.; depth, 0.04 mm.

Megalotrocha.

M. alboflavicans, Ehrenberg. Common.

Conochilus.

**C. volvox.*

C. dossuaris, Hudson. Heidelberg.

There is another form of this genus occurring plentifully, which approaches *C. unicornis*, *Rousselet*, in general characters. There are, however, differences in the position of the dorsal antenna, and the form of the coronal disc, as well as the distinct bifurcation of the antenna at its distal end, which, when compared with Rousselet's figure, suggests varietal if not specific difference. I trust to have further opportunity of studying this animal.

Order II.—BDELLOIDA.

Family.—Philodinadae.

Philodina.

**P. roseola.*

**P. citrina.*

P. megalotrocha, Ehrenberg. Mr. W. Stickland.

Rotifer.

**R. vulgaris.*

**R. tardus.*

R. macrurus, Schrank. Carrum.

R. megaceros, Gosse. Mr. W. Stickland.

Actinurus.

A. neptunius, Ehrenberg. Heidelberg.

Callidina.

A number of forms of this genus have been seen, but not certainly identified.

Order III.—PLOIMA.

Sub-Order.—ILLORICATA.

Family.—Microdidae.

Microdon.

M. clavus, Ehrenberg. Springvale.

Family.—Asplanchnadae.

**A. brightwellii.*

A. amphora, Hudson. Brighton, Caulfield.

There are several other forms of this genus commonly found presenting characters somewhat inconsistent with described species, and further investigation is necessary to elucidate them.

Asplanchnopus.

**A. myrmeleo.*

Sacculus.

S. viridis, Gosse. Mr. Stickland.

Syncheta.

**S. pectinata.*
**S. tremula.*
S. baltica, Ehrenberg. · Open water of Port Phillip.

Family.—Triarthradae.

Polyarthra.

**P. platyptera.*

Triartha.

**T. longiseta.*

Family.—Hydatinadae.

Hydatina.

**H. senta.*

Notops.

N. clavulatus, Ehrenberg. Heidelberg, Brighton and Camberwell.

N. brachionus, Ehrenberg. Wodonga and Camberwell.

Family.—NOTOMMATADAE.

Taphrocampa.

T. saundersiae, Gosse. Mr. Stickland.

Notammata.

**N. aurita.*

**N. ansata.*

**N. naias.*

Copeus.

**C. ehrenbergii.*

C. labiatus, Gosse. Camberwell. Mr. W. Stickland.

C. caudatus, Collins. Botanical Gardens, Melbourne.

C. pachyurus, Gosse. Cheltenham.

Proales.

P. decipiens, Ehrenberg. Heidelberg.

P. petromyzon, Ehrenberg. Yarra Glen.

Furcularia.

F. longiseta, Ehrenberg. Wimmera River, Horsham; Woodend.

F. equalis, Ehrenberg. W. Stickland.

Eosphora.

E. digitata, Ehrenberg. Yarra Glen.

Diglena.

**D. catellina.*

D. biraphis, Gosse. Heidelberg.

Sub-Order.—LORICATA.

Family.—Rattulidae.

This family has been most ably treated by Prof. Jennings in his "Monograph of the Rattulidae" (U.S. Fish Commission, Bull. for 1902, pp. 273-352), and his nomenclature is used in naming the species. In future the work of identifying this family should be much simplified.

Rattulus.

**R. carinatus*, Lamarck. (= *Mastigocerca carinatus*, Ehr.)

R. rattus, Muller. (= *M. rattus*, Hudson and Gosse.) Mr. W. Stickland.

R. elongatus, Gosse. (= *M. elongata*, Gosse.) Brighton, Woodend.

R. longiseta, Schrank. (= *Mastigocerca bicornis*, Hudson and Gosse.) Yarra Glen.

Diurella.

D. porcellus, Gosse. (= *Coelopus porcellus*, Gosse.) Heidelberg.

Family.—Dinocharidae.

Dinocharis.

* *D. tetractis.*

Scauridium.

S. longicaudum, Ehrenberg. Mr. W. Stickland.

Stephanops.

* *S. muticus.*

S. lamellaris, Ehrenberg. Mr. W. Stickland.

Family.—Salpinadae.

Diachiza.

* *D. semiaperta.*

S. eustala, Gosse. Heidelberg.

Family.—EUCHLANIDAE.

Euchlanis.

* *E. dilatata.*

E. triquetra, Ehrenberg. Brighton.

Family.—CATHYPNADAE.

Cathypna.

C. spenceri, Shephard (Proc. Roy. Soc. Victoria, vol. iv., 1892, p. 77, and Victorian Naturalist, vol. 9, 1892, p. 15).

This species was described in the first quoted journal, but no name applied, the specific name being given in the Victorian Naturalist as cited.

C. luna, Ehrenberg. Mr. W. Stickland.

Distyla.

* *D. ichthyoura.*

Monostyla.

* *M. quadridentata.*

M. bulla, Gosse. Willsmere.

M. lunaris. Willsmere.

Family.—COLURIDAE.

Colurus.

* *C. bicuspidatus.*

C. obtusus, Gosse. Mr. W. Stickland.

C. amblytellus, Gosse. Carrum.

Metopidia.

* *M. solidus.*

M. vitrea, Shephard. (= *M. ovalis,* Shephard.) (Anderson and Shephard, Proc. Roy. Soc. Victoria, vol. iv., 1892, p. 78, pl. 12.)

In originally naming this species it was, unfortunately, overlooked that the name "ovalis" had been used by Ehrenberg.

M. oysternum, Gosse. Willsmere.

Family.—PTERODINADAE.

Pterodina.

**P. intermedia.*

P. patina, Ehrenberg. Treasury Gardens, Melbourne.

P. reflexa, Gosse. Mr. W. Stickland.

P. valvata, Hudson. Mr. W. Stickland.

**P. trilobata*, Shephard.

A form has been discovered in South Africa which Mr. Rousselet considers specifically identical with this form, though much larger in size. The measurement given in the original description was 1/250 in. or 0.102 mm. The length of the South African form was stated as 1/76 in., or .334 mm. I have had several opportunities of examining specimens of *M. trilobata* from different localities since the form was first described, and the results of two series of measurements were:—Length of lorica, 0.21 mm. and 0.19 mm.; breadth, 0.19 mm. and 0.18 mm. respectively.

This form has been collected at Sandringham, Rosstown, and Yarra Glen, some thirty miles apart. Specimens examined quite recently were in close agreement with Mr. Dixon-Nutall's figure in the position of the lateral antennae, the form of the gastric glands, and general appearance, excepting the bosses on the loria, which were absent.

Family.—BRACHIONADAE.

Brachionus.

**B. rubens.*

**B. bakeri.*

B. bakeri, var. *brevispina*, Rousselet. Heidelberg.

B. mülleri, Ehrenberg. Carrum and Warrnambool. In brackish water.

B. urceolaris, Ehrenberg. Mr. W. Stickland.

B. militaris, Ehrenberg. Heidelberg.

B. falcatus, Zacharias.

This very striking form was found at Willsmere, and comparison with European specimens kindly sent to me by Mr. Rousselet left no doubt as to its identity. The four very prominent anterior and posterior spines differed in length and curvature, but not to the extent found in some other species of the genus. The dimensions of the specimens were:—Length of lorica, without spines, 0.15 mm.; total length, 0.45 mm.; breadth, 0.15 mm.

B. angularis, Gosse. The forms found vary from the figures given in "The Rotifera." A comparison made between actual specimens may establish a variety. The points of agreement are, however, such as to suggest that the discrepancies may be due to inadequate figuring of the European specimens.

B. lyratus, n.sp. (Plate XXI., figs. 5 and 6) Templestowe and Black Rock. This form, viewed on the dorsal surface, is of ovate outline, swelling towards the lumbar region. At the anterior two short outwardly curved spines are placed on either side of a notch occupied by a well-developed dorsal antenna, and on each side of these spines there is a pair of slight acute prominences. At the posterior end there is a deep, squarish recess, made deeper by two knobbed projections which curve outwards in a manner suggesting the form of a lyre. A lateral view shows the lorica to be arched dorsally, being highest towards the posterior end; the ventral surface is flat. Viewed ventrally the lorica possesses a wavy outline at the anterior, with two lines running backwards and inwards on either side. These two lines are, I believe, a view of the edges of two triangular plates so placed as to cause the lorica to gape and thus form an opening for the protrusion of the corona; whether these plates are flexible, and thus permit of closure of the opening, was not determined. The animal is of a pale brownish colour. The lorica is covered with minute papillae, and is indistinctly faceted. The small lumbar antennae occur in the usual position. The corona, foot, mastax, eye and internal structure generally present the characters usual in the genus. Dimensions:—Length of lorica, 0.16 mm.; breadth, 0.135 mm. Heidelberg.

B. dichotomus, n.sp. (Plate XXII., figs. 3 and 4). This form was met with in the same gathering as *B. lyratus*. Dorsally, the lorica presents a somewhat ovate shape, truncated anteriorly and provided with two long spines branching outwards so as to form a V-shaped notch between them, and curving inwards at their free ends. Posteriorly two still longer straight spines are set so as to form a broad curve between them. There is also at the posterior end, overhanging the bases of the spines, a projecting plate having a gentle outward curve in the centre, and then sweeping outwards at each side to form two short acute points. Ventrally the lorica shows the same outline excepting the anterior portion, which reveals a flap-like appearance of similar arrangement to that of *B. lyratus*. The lorica is transparent and very faintly stippled. The dorsal antenna is of considerable length, and the lumbar pair are very small and placed quite at the lateral edges. The long foot, corona, eye and internal organs agree with those of the genus generally. The length of the lorica without spines is 0.12 mm. ; over all, 0.3 mm. ; breadth, 0.1 mm.

Family.—ANURAEADAE.

Anuraea.

* *A. curvicornis.*

* *A. aculeata.*

A. cochlearis, Gosse. Cheltenham.

Several other forms of this genus are known, but in view of the variability of the genus they have been left for further study.

Order.—SCIRTOPODA.

Family.—PEDALIONIDAE.

Pedalion.

P. mirum, Hudson.

This form is quite common in the lagoons of the Yarra valley. Some slight differences as compared with Hudson's description have been noted, and more scrutiny is needed, but it appears unlikely that more than varietal differences will be established.

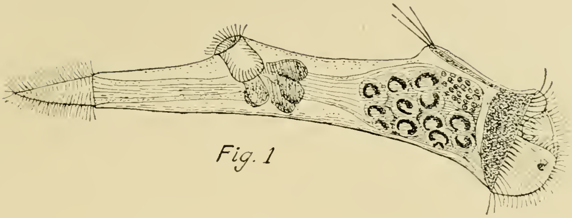

Fig. 1

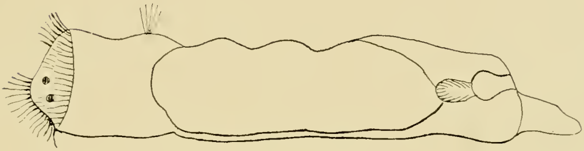

Fig. 2

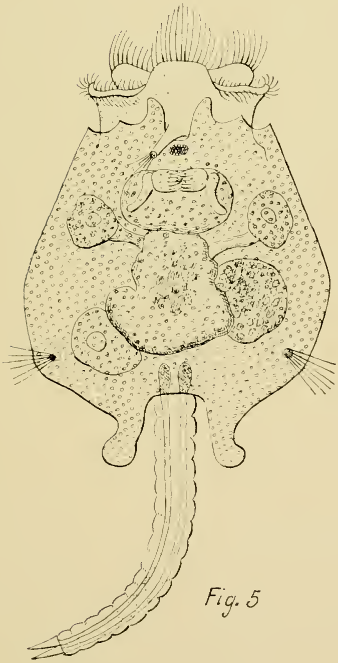

Fig. 5

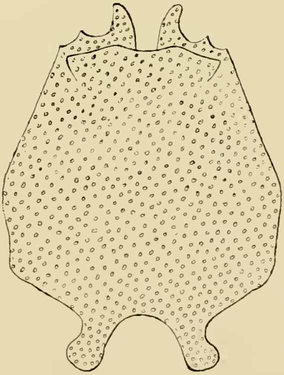

Fig. 6

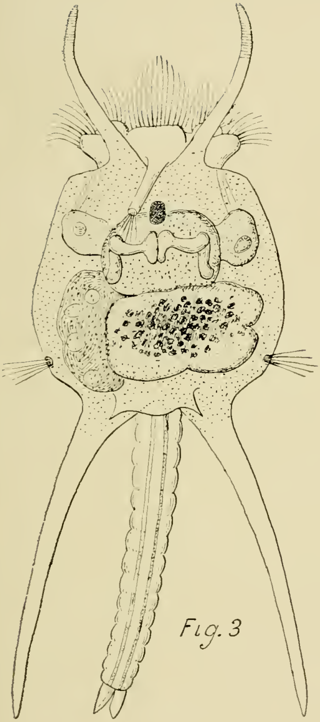

Fig. 3

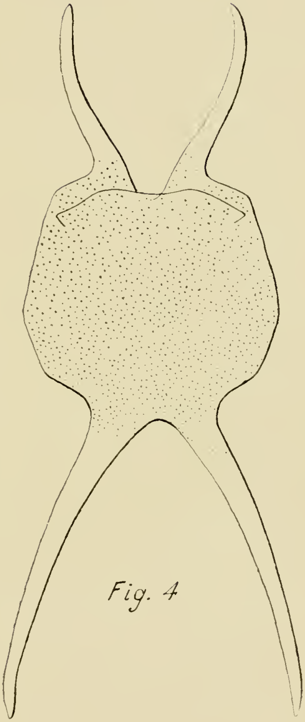

Fig. 4

[PROC. ROY. SOC. VICTORIA, 24 (N.S.), PT. I., 1911.]

ART IV.—*Fruiting of "Blackfellow's Bread" (Polyporus Mylittae, Cooke).*

BY ALFRED J. EWART, D.SC., PH.D., F.L.S.

(Government Botanist of Victoria and Professor of Botany and Plant Physiology in the Melbourne University).

[Read 20th April, 1911].

As is now well known, "Blackfellow's Bread" is the subterranean sclerotium of a *Polyporus*, whose mycelium grows, possibly partly saprophytically and partly parasitically, on the roots of forest trees. The sclerotia, which often attain a considerable size, and may weigh 10 to 20 lbs., simply represent a large store, chiefly of carbo-hydrate material, mainly in the form of fungal cellulose stored up for the nourishment of the large Polyporus-like sporophores which are formed under special conditions.

The sporophore, or fruiting body, appears to have been first observed by Mr. Tisdall,[1] but its importance in determining the classification of the fungus was not determined until a specimen reached the mycologist Cooke, who, in a paper issued in the Gardener's Chronicle for 1892, under the title, "A Mystery Solved," placed it under the genus *Polyporus*. Fruiting specimens were subsequently described in detail by Mr. R. T. Baker,[2] and by Mr. D. McAlpine.[3] The last-named gentleman gives photographs of the fruit and also of the spores.

For some time I have attempted to obtain fruits of the fungus by keeping the sclerotes buried in moist soil in a greenhouse for long periods of time, but without success. The cause of the non-formation of the fruiting bodies could not be determined until it was found that, as in the case of certain other *Polypori*, the formative stimulus of light is necessary to induce the formation of sporophores. For instance, a large specimen weighing, originally, over 12 lbs., was kept buried in soil in a pot for 2½ years. At the end of that time, although somewhat shrivelled and slightly rotted in parts, it was otherwise unaltered. On exposing it to light in the same greenhouse in which the pot had remained the whole of the time, within two days white pustules appeared, these developing from cracks on the side and upper surface af the sclerote. In four days one of these developed into a large *Polyporus* fructification, 5 inches in diameter, with a somewhat irregular margin and a short stalk, and two additional small outbreaks of pustules developed later to similar fructifications. On a darkened portion and on the under surface, no development of fruits took place. The power of developing a hymenium is not confined to the surface of a sclerote, for spore-bearing tubes may develop directly from the central portion of the fruit when this is cut in two. Mr. McAlpine noted that on the under side of a slice, groups of tubes formed on the surface, without any properly stalked fruit body being produced, whereas on the upper surface, a normal sporophore appeared. He concluded that the former peculiarity was due to the fact that on the under surface, the formation of a sporophore was physically impossible. This is, of course, not the case, for many fungi will develop sporophores when the rudiment starts in the inverted position, the stalk usually bending so that the pileus or cap is developed in the normal position. Similarly, the sporophores of *Polyporus* are able to develop against far greater pressures than would be represented by the weight of a slice of the sclerote. Actual experiments showed that the same formation of groups of sessile tubes, instead of a stalked sporophore, took place on slices placed with their cut surface vertical, where there was no physical resistance to the formation of a stalked sporophore. Evidently, therefore, neither the influence of gravity nor that of light can be responsible for the non-formation of the usual regular stalked sporophore in such cases. Apparently, cutting the sclerote into slices produces a profound disturbance in the morphogeny of the sporophore, which usually breaks through cracks in the outer surface. The removal of the mutual pressures exercised by the central tissues at the cut surface as well as the cessation of their reciprocal formative or inhibitory influence on the free surface at least, probably leaves each part of the exposed surface free to exercise its spore forming tendency in the most direct possible manner, which is by the immediate formation of hymenel tubes without the intervention of a sporophore.

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[1] Victorian Naturalist, 1885 and 1886, p. 19.
[2] Proc. Linn. Soc. New South Wales, 1902.
[3] Journal of Agriculture of Victoria, 1903, vol. ii., p. 1017

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. V.—*Contributions to the Flora of Australia, No. 17.*[1]

BY

ALFRED J. EWART, D.Sc., Ph.D., F.L.S.
(Government Botanist of Victoria and Professor of Botany and Plant Physiology in the Melbourne University);

BERTHA REES and BERTHA WOOD
(Government Research Scholars).

(With Plate XXIII.).

[Read 11th May, 1911].

Acacia salicina, Lindl. (Leguminosae).

This plant was recorded from Wilson's Promontory on the authority of a specimen named by Mueller in 1853. This proves to be an error for *A. retinodes*, which is already recorded for the South and South-West, as well as for the North-West of Victoria, whereas *A. salicina* is confined to the North-Western district. The Flora of the National Park decreases by one, since *A. retinodes* has already been recorded.

Anthocercis litoria, Lab. (Solanaceae).

Central Greenough, North-West Australia, Max Koch, Sept., 1910, No. 2101.

Bartsia Trixago, L. "Trixago Bartsia." (Scrophulariaceae).

Geelong, Victoria, H. B. Williamson, Nov., 1910. No. 1428.

This naturalised alien has only previously been recorded in Victoria from Broadmeadows.

Brachycome calocarpa, F. v. M. (Compositae).

Bacchus Marsh District, Victoria, J. R. Tovey and C. French Jnr., Nov., 1910, Geelong, Victoria, H. B. Williamson, Jan., 1911, No. 1439.

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[1] No. 16 in Proc. Roy. Soc. Victoria, vol. xxiii., p. 285 (1911).

New localities in this State for this plant, only previously recorded from the North-West.

BROMUS MAXIMUS, Desf. (Gramineae).

[1]Yarra River, F. Mueller; [2]Ravenswood, Victoria, Bissill: Campaspe River, C. W. Holloway, 1885; Stawell, W. E. Mathews, 1893; Strathbogie Ranges, W. Gates, 1891; Grampians. C. Walter, 1900; Near Dimboola, F. M. Reader, 1887, and others.

This plant was recorded as *B. sterilis* by Bentham, with which species it is closely allied, differing chiefly in its stouter character, larger and less drooping spikelets and stouter awns. Mr. Maiden and the Kew authorities recognise it as a distinct species, and hence for the sake of uniformity the original records of *B. sterilis* may be reduced to the following:—

BROMUS STERILIS, L. (Gramineae).

Upper Goulburn River, Victoria, A. D. Hardy, 1894; Goulburn Valley, Victoria, G. H. Robinson, 1894; Dookie, Victoria, H. Pye, 1909 (?). Near the Junction of the Murray and Darling Rivers, Miss Holding, 1895, also Lake Bonney, South Australia, Mrs. Wehl, 1882.

CALANDRINIA STROPHIOLATA, F. v. M. (Portulaceae).

Central Greenough, North-West Australia, Max Koch, Sept., 1910, No. 2097.

CALANDRINIA VOLUBILIS, Benth. (Portulaceae).

Bacchus Marsh District, Victoria, J. R. Tovey and C. French Jnr., Nov., 1910.

A new locality in Victoria for this plant, previously recorded from the North-West. This species was recorded by Mr. Walter in the Vict. Nat., Vol. XVI., p. 100, from the South, but there were no specimens from the South in Walter's Herbarium, purchased by the Government for the National Herbarium.

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[1] Recorded in Benth. Fl. Aust., vol. vii., p. 662 as *B. sterilis*.

[2] This was recorded in Benth. Fl. Aust., l.c., as *B. sterilis*, but placed as from a Tasmanian locality, which is evidently a mistake.

CALLITRIS RHOMBOIDEA, R. Br. var. TASMANICA. (Coniferae).

Deal Island, Kents Group, Judge Dobson, 1884.

This was at first considered to be possibly a new species, and was submitted to Dr. Koorders for critical examination, who found it to be unlike any species in the Buitenzorg Garden or Herbarium. On further examination it appears, however, to be referable to the variety "*tasmanica*" of *C. rhomboidea*, which R. T. Baker raises to specific rank largely on account of its somewhat different appearance in the field.

Bentham gives as its distinguishing characters:—Cones, ½ to ¾ inches thick, and rugose at the back, the dorsal point or prominence less distinct than in the variety "*mucronata.*" (It is more distinct than in the type. It is, in fact, doubtful if the variety "*mucronata*" is valid, since the development of the dorsal prominence varies even on the same specimen.)

Baker merges both these varieties into his *Callitris tasmanica.*

CALOTHAMNUS HOMALOPHYLLUS, F. v. M. var. ANGUSTIFOLIA, Ewart n. var. (Myrtaceae).

Central Greenough, West Australia, Max Koch, Sept. 1910, No. 2086.

The leaves on this variety are much longer and narrower than the type, 2 to 3 inches long, 2 to 3 mm. broad. Fruits are a little smaller than usual, and prominently warted.

A specimen from the Upper Irvine and Champion's Bay, placed by Mueller as *C. homalophyllus* var., is intermediate in its leaves between this variety and the type.

CALOTIS LAPPULACEA, Benth. (Compositae).

Bacchus Marsh District, Victoria, J. R. Tovey and C. French Jnr., Nov., 1910.

A new locality for this plant, previously recorded in Victoria from the North-West and North-East.

CHENOPODIUM AMBROSIOIDES, L. "Mexican Tea." (Chenopodiaceae).

Lowden, Preston River, West Australia, Max Koch, Oct., 1909, No. 2093.

This weed, a native of America, has established itself in Queensland, New South Wales, Victoria and Western Australia. It is not recorded for South Australia in Black's Naturalised Flora of South Australia, but is sure ultimately to reach that State, if not already present.

CHORIZEMA RHOMBEUM, R. Br. (Leguminosae).

Kirrup, West Australia, Max Koch, No. 2089, October, 1910.

DAMPIERA LINEARIS, R. Br. (Goodeniaceae).

Wooroloo, West Australia, Max Koch, Oct., 1907, No. 2034.

Lowden, Preston River, West Australia, Max Koch, Oct., 1909, No. 1997.

DIPSACUS FULLONUM, L. "Fuller's Teazel." (Dipsaceae).

Moorabool Valley, Victoria, J. G. O'Donoghue, December, 1910.

A native of Europe, previously recorded as a garden escape, now apparently naturalised in Victoria.

DROSERA PETIOLARIS, R. Br. (Droseraceae).

Napier-Broome Bay, North-West Australia, G. F. Hill, Feb., 1910, No. 108.

A small slender form.

EPACRIS HETERONEMA, Labill.

This has been subdivided by Dr. Stapf into four separate species (Kew Bulletin, No. 7, 1910, p. 213), namely, *E. heteronema*, *E. breviflora*, *E. bawbawiensis* and *E. Stuartii*. The characters relied on—namely, the relative length and shape of the flowers, style, etc.—appear to be valid and constant distinguishing features. To the localities mentioned by Stapf the following may be added:—

E. BAWBAWIENSIS, Stapf.

Mt. Erica, Bawbaw Mts., C. Frost, 1895; G. Weindorfer, Dec., 1904; H. B. Williamson, Jan., 1905.

E. breviflora, Stapf.

Clarence River, N.S.W., Beckler; Ex Hort. Bot. Berolinensis, June, 1847; Strathbogie, N.E. Victoria, Nov., 1901, A. W. Vroland.

E. heteronema and *E. Stuartii* are solely Tasmanian, *E. breviflora* comes from New South Wales and Victoria, while *E. bawbawiensis* is Victorian only.

Ephedra distachya, L. "Shrubby Horsetail" (Gnetaceae).

Sandringham, Victoria, C. S. Sutton, April, 1911.

A native of Europe and North America, now growing as a garden escape near Sandringham.

Eragrostis major, Host. "Large Love Grass." (Gramineae).

Mooroopna, Goulburn Valley, Victoria, J. P. McLennan, 1911.

This grass was recorded in the Weeds, Poison Plants and Naturalised Aliens of Victoria as a garden escape. It has now evidently established itself, and may be considered naturalised.

It is a native of the tropical and sub-tropical regions.

Eriochilus scaber, Lindl. (Orchidaceae).

Swan Mill, Lowden, Preston River, West Australia, Max Koch, Sept., 1910.

This specimen approaches towards *E. tenuis* in having solitary flowers, narrow leaves, and in being less hairy.

Erysimum repandum, L. "Treacle Mustard." (Cruciferae).

Northcote, Victoria, W. R. A. Baker, Jan., 1911, Foreshore, Geelong, H. B. Williamson, December, 1910, No. 1449.

This troublesome member of the *Cruciferae* has only been previously recorded from the North-Western portion of Victoria.

Eucalyptus eugenioides, Sieber var. nana, Maiden and Deane. (Myrtaceae).

Near Orbost, Gippsland, Victoria, P. R. St. John, December, 1910.

This variety has not previously been recorded for Victoria.

EUGENIA ANGOPHOROIDES, F. v. M. (Myrtaceae).

Napier-Broome Bay, North-West Australia, G. F. Hill, December, 1909, No. 24.

Only previously recorded from Queensland.

EWARTIA, BEAUVERD, gen. nov. (Compositae—Gnaphalioideae).

In the "Bulletin de la Sociètè Botanique de Genève," page 236, 1910, Beauverd raises this new genus on the basis of two species and a variety classed by Mueller in his Census of Australian Plants as *Leontopodium Catipes*, *L. Catipes* var. *nubigena* (*Antennaria nubigena*), and *L. Meridithae*, but which have been referred at different times to the following genera:—*Gnaphalium*, *Raoulea*, *Antennaria* and *Leontopodium*.

The following records may now be noted in addition to those given by Beauverd:—

EWARTIA CATIPES, (D.C.) Beauverd.

Victoria.—Mount Hotham, C. Walter, January, 1888.
Victorian Alps, D. Sullivan, 1885.
Tasmania.—Glenorchy, Simpson, 1881.
Ben Lomond, 20/1/1878.

EWARTIA NUBIGENA, (F. v. M.), Beauverd.

Victoria.—Bogong Range, 6000 feet.
Upper Mitta Mitta, Miss Campbell, 1882.
Tasmania.—Ben Lomond, Aug. Simson, 1892.
N.S. Wales.—Mt. Kosciusko, F. Findlay, 1882, and Stirling, 1889.
Snowy Mountains, W. Bauerlen, Feb., 1890.

EWARTIA MERIDITHAE (F. v. M.), Beauverd.

Tasmania.—Mt. Zeehan, W. Fitzgerald, 1894.

The first-named species is therefore Victorian and Tasmanian, the second is a native of Victoria, Tasmania and New South Wales; the third is Tasmanian only.

FESTUCA RUBRA, L. "Red Fescue." (Gramineae).

Neerim Junction, Gippsland, Victoria, H. S. Wheeler, Dec., 1910.

This naturalised alien has only been recorded previously in Victoria from the North-East.

GASTROLOBIUM TRILOBUM, Benth. (Leguminosae).

The only localities for this West Australian species given in Bentham's Flora Australiensis, vol. II. p. 101, are:—

Swan River, Drummond; near Williams, Preiss, No. 825. The former specimen was the only one represented in the National Herbarium, Melbourne, but now the following additional localities may be reported:—Cut Hill, York, West Australia, O. H. Sargent, 1908; Mt. Caroline, Miss Sewell, 1890; Sources of the Swan River, Miss A. Eaton, 1889; Bunkin, near Lake Wagin, Miss M. Cronin, 1890.

The specimens from the two latter localities are in fruit, which may now be described as follows:—

Pod 6 mm. long, 3 mm. broad, elongate—ovate, with a short blunt terminal upwardly bent beak, on a distinct stalk 4 mm. long, projecting beyond the calyx.

GLYCERIA FORDEANA, F. v. M. (POA HACKELI, F. M. Reader). (Gramineae).

County of Borung, Victoria, F. M. Reader, Sept. to Nov., 1903-4.

This is the type specimen of *Poa Hackeli*, F. M. Reader, described in the "Victorian Naturalist," Vol. XXIII., page 89 (1906).

As a prior *P. Hackeli* already existed the name could not stand in any case, but as the only difference between this plant and the type *Glyceria Fordeana*, lies in the fact that the spikelets of the latter are usually 8 to 12 flowered, and those of the former usually 6 to 9 flowered, the species may safely be suppressed.

In all other respects there is complete agreement with *Glyceria Fordeana*, and the number of flowers in the spikelets may vary from 6 to 12 on the same specimen.

GRATIOLA PERUVIANA, L. (Scrophulariaceae).

Preston River, West Australia, Max Koch, Oct., 1909, No. 2019.

GREVILLEA AGRIFOLIA, A. Cunn. var. MAJOR, Ewart and Rees. n. var. (Proteaceae).

Mission Station, Napier-Broome Bay, West Australia, G. F. Hill, December, 1909, No. 22.

The variety differs from the type in its larger leaves (5-6 inches long, including petiole, by 2 to 5 inches broad), perianth minutely hairy outside, fruit larger than in most specimens. The seeds, not previously described, are surrounded by a pale membranous wing 1-2 lines broad, and have a dark brown surface mottled with a greyish skin.

HELICHRYSUM CORDATUM, D.C. (Compositae).

Wooroloo, West Australia, Max Koch, Oct., 1908, No. 2028.

ISOETOPSIS GRAMINIFOLIA, Turcz. (Compositae).

Bacchus Marsh District, Victoria, J. R. Tovey and C. French Jnr., Nov., 1910.

A new locality for this plant, only previously recorded in Victoria from the North-West and South-West.

LACHNOSTACHYS VERBASCIFOLIA, F. v. M. (Verbenaceae).

(M. Koch, No. 2100. 50 miles beyond Central Greenough, North-West Australia, J. G. Young, Sept., 1910.

Not previously recorded so far North.

LAXMANNIA SESSILIFLORA, Decne. (Syn. BARTLINGIA SESSILIFLORA, F. v. M.). (Liliaceae).

On sandy patches at Lowden, Preston River, West Australia, Max Koch, October, 1909, No. 2092.

LESCHENAULTIA LINAROIDES, D.C. (Goodeniaceae).

Central Greenough, North-West Australia, Max Koch, Sept., 1910, No. 2098.

LEUCOPOGON CONOSTEPHIOIDES, D.C. (Epacrideae).

Lowden, Preston River, West Australia, Max Koch, August, 1908, No. 1893.

LEUCOPOGON OXYCEDRUS, Sond. var. BREVIFOLIUS, Benth.

(*L. rotundifolius, Br. var. oblongatus*, Sond.) (Epacrideae).

Bentham, in his Flora Australiensis, Vol. IV., page 214, states that *Leucopogon rotundifolius var. oblongatus*, Sond. in Plantae Preiss, 1, 324, may possibly be the same as the variety *brevifolius* of *Leucopogon oxycedrus.*

The species *rotundifolius* and *oxycedrus* differ in the length of the corolla-tube and lobes, and the variety "oblongatus" agrees more closely with *L. oxycedrus* than with *L. rotundifolius.* The term *brevifolius* applied to the variety of *oxycedrus* seems rather a misnomer, since the leaves differ more in breadth than in length from the type.

The No. 309 of Drummond's fifth collection has narrow leaves, and seems closer to the type form than to the variety. The Gordon Plains specimen of Maxwell also quoted by Bentham is, however, practically identical with those previously placed under *L. rotundifolius*, var. *oblongatus*, which name is a synonym for *L. oxycedrus* var. *brevifolius.*

LINARIA VULGARIS, L. "Common Toad Flax." (Scrophulariaceae).

Drouin, Victoria, J. P. McLennan, 1911.

This plant was previously recorded as a garden escape at Bloomfield, Gippsland, in the Contributions to the Flora of Australia, No. 14, but is now evidently spreading as a naturalised alien in this State.

LORANTHUS SANGUINEUS, F. v. M. var. PULCHER, Ewart n. var. (Loranthaceae).

Napier-Broome Bay, North-West Australia, G. F. Hill, April, 1910, No. 156.

The flowers are 2½ instead of 1½ inches long, and the leaves shorter and broader than usual, but otherwise the plant agrees with the type specimens.

LYPERANTHUS SERRATUS, Lindl. (CALADENIA SERRATA, Reichb.) (Orchidaceae).

Lowden, Preston River, West Australia, Max Koch, Oct., 1910, No. 2081.

This and the allied species *L. suaveolens*, R. Br., were placed by Bentham under *Caladenia* in the Flora Australiensis, Vol. VI., pp. 385 and 6, but their affinities are undoubtedly with *Lyperanthus*.

MARIANTHUS PICTUS, Lindl. (Pittosporeae).

Near Cut Hill, York, West Australia, O. H. Sargent, No. 442.

This plant is sometimes known as *M. lineatus*, F. v. M., which is distinguished by its denser corymbs, shorter and stouter pedicels. These are, however, variable characters, and Baron von Mueller mentions in his Fragmenta, Vol. XII., page 3, that the supposed difference in the seeds does not exist. *M. lineatus* is therefore only a synonym for *M. pictus*. The former name was dropped by Mueller in his last Census.

MATRICARIA GLOBIFERA, Fenzl. "Globular Chamomile." (Compositae).

Coode Island, Victoria, J. R. Tovey and C. French Jnr., Oct., 1908. Foreshore, Geelong, Victoria, H. B. Williamson, Jan., 1911, No. 1450.

A native of South Africa. Apparently naturalised around the shores of Port Phillip.

MELILOTUS MESSANENSIS, All. "Mediterranean Melilot." (Leguminosae).

Geelong, Victoria, H. B. Williamson, Nov., 1906 and 1910, No. 1338.

A native of the Mediterranean regions. Apparently naturalised around the shore of Port Phillip, near Geelong.

OLAX STRICTA, R. Br. (Olacinaceae).

Cape Everard, Victoria, P. R. St. John, December, 1910.

Apparently the first specimen collected in Victoria.

O. stricta was recorded as Victorian in Mueller's Second Census of Australian Plants, but there was no Victorian specimen of this species in the National Herbarium.

ORTHOCARPUS PUSILLUS, Benth. (Scrophulariaceae).

Chiltern, Victoria, Comm. by H. B. Williamson, Nov., 1910.

This naturalised alien has only been previously recorded from the South-West.

OXYLOBIUM ALPESTRE, F. v. M. (Leguminosae).

Mentone, Victoria, C. Roberts, August, 1910, Jan., 1911.

The plant is usually alpine. The present specimens have broader and more hairy leaves than usual, some being slightly hairy on the upper surface. The stipules are, however, distinct, and the pod also that of the above species, instead of the closely allied *O. ellipticum.* The descent of alpine plants to coastal localities is not uncommon.

PIMELEA ARGENTEA, R. Br. (Thymeleae).

Central Greenough, North-West Australia, Max Koch, Sept., 1910, No. 2087.

POLYGALA MYRTIFOLIA, L. "Myrtle-leaved Milkwort." (Polygalaceae).

Near Perth, Western Australia, F. Stoward, April, 1911.

This South African plant, which has long been recorded in Victoria as a naturalised alien, has now evidently established itself in Western Australia.

POTENTILLA RECTA, L. "Erect Potentil." (Rosaceae).

Penshurst, Victoria, H. B. Williamson, Nov., 1909, No. 1432.

A native of Europe, apparently only a garden escape.

PTEROSTYLIS APHYLLA, Lind. P. PARVIFLORA, R. Br. (Orchidaceae).

Pterostylis aphylla, Lindl., was considered to be a form of *P. parviflora*, R. Br., by F. v. Mueller, Fitzgerald and Reader. Mueller afterwards entered *P. aphylla* in his MS. Census as a distinct species.

In Bentham's Flora Australiensis, Vol. VI., both are given as distinct species but closely allied, the differences being—(1) smaller size, (2) radical leaves absent at flowering, (3) galea broader and more obtuse, (4) basal appendage of labellum obtuse and without the three terminal setae. The characters 1 and 2 are not reliable in orchids, being influenced by the local, seasonal and other conditions. Specimens with broader and obtuse galea have the three terminal setae, and others with narrower and more pointed galea have the labellum, supposed to characterise *P. aphylla.* The latter is in fact hardly even distinguishable as a well-defined variety of *P. parviflora.*

PTEROSTYLIS NANA, R. Br. var. PYRAMIDALIS. (P. pyramidalis). (Orchidaceae).

Lowden, Preston River, West Australia, Max Koch, Sept., 1910, No. 2083.

Bentham distinguishes this as a separate species on the basis of the bracts of the stem being more leaf-like and the basal leaves less distinctly rosulate. These are not, however, constant characters, and the flower is identical with that of *P. nana,* in which the species was included by Mueller.

RAPHANUS RAPHANISTRUM, L. "Wild Radish or Jointed Charlock." (Cruciferae).

Central Greenough, North-West Australia, J. G. Young, per Max Koch, Sept. 1910, No. 2099.

This naturalised alien, a native of Europe, Asia and Africa, is now widely distributed in the Central Greenough District of North-West Australia.

SECALE CEREALE, L. "Common Rye." (Gramineae).

Geelong, Victoria, H. B. Williamson, 1910, No. 1431.

Possibly an escape from cultivation.

SETARIA NIGRIROSTRIS, Durand and Schinze. "Black-beaked Setaria." (Gramineae).

This plant is sometimes classed as *S. imberbis,* sometimes as *S. ambigua,* and also as a variety of *S. viridis,* and it was included under the last-named species in the Weeds of Victoria. *S. viridis* is, however, annual, whereas the present plant is undoubtedly perennial, and is hence recognised as a distinct species as above. (See also Flora Capensis, Vol. VII., p. 423, 1900).

SOLANUM ESURIALE, Lindl. "Edible Nightshade." (Solanaceae).

Shire of Numurkah, Victoria, B. Lancaster, March, 1911.

Only previously recorded in Victoria from the North-West, it is now apparently spreading towards the East of Victoria, where in former years it did not grow.

STENOPETALUM ROBUSTUM, Endl. (Cruciferae).

Busselton, West Australia, Max Koch, Sept., 1909, No. 1969.

STIPA ELEGANTISSIMA, Lab. (Gramineae).

Bacchus Marsh District, Victoria, J. R. Tovey and C. French Jnr., Nov., 1910.

New locality in Victoria for this grass; only previously recorded from the North-West and South-West.

STYLIDIUM PILOSUM, Lab. (Stylideae).

On rocks, Lowden, Preston River, West Australia, Max Koch, Oct., 1909, No. 1933.

This was given in the 16th Contribution to the Flora of Australia in the Proc. of the Roy. Soc. of Vict., Vol. XXIII., p. 300, as *Stylidium reduplicatum*, R. Br. These two species are very closely allied, differing mainly in the inflorescence. The majority of the specimens in the National Herbarium placed under *S. reduplicatum*, proved on critical examination to be *S. pilosum*.

STYLIDIUM REDUPLICATUM, R. Br. (Stylideae).

Lowden, Preston River, West Australia, Max Koch, Oct., 1910, No. 2085.

STYLIDIUM SCANDENS, R. Br. (Stylideae).

Kirrup, West Australia, Max Koch, Oct., 1910, No. 2075.

THELYMITRA EPIPACTOIDES, F. v. M. in Fragm. Vol. V., 174 (1866). "Stout Hood-Orchid." (Orchidaceae).

The Kew Index gives this plant as a synonym for *T. canaliculata*, R. Br. Bentham suggested that it might be a broad-leaved form of *T. ixioides* or *T. canaliculata.* The latter appears itself to be a slender variety of *T. ixioides*, whereas *T. epipactoides* is stouter, has larger flowers and has the middle lobe of the labellum more in one piece (Fig. 7 shows an extreme case of lobing). Its affinities are more with *T. aristata* than with *T. epipactoides.*

The species is given in Mueller's Second Census of Australian Plants as Victorian only, but Dr. Rogers has since recorded it in Trans. of the Roy. Soc. of S.A., Vol. XXXIII., p. 262 (1909), from South Australia.

The following Victorian localities for this apparently rare orchid might be mentioned:—

Port Phillip, C. French, Oct., 1887, Sandringham, C. French Jnr. and C. Walter, Oct., 1900, North-West Victoria, F. M. Reader, Jan., 1893. It therefore occurs from Port Phillip to the North-West of Victoria, thence extending into South Australia.

TRITONIA LINEATA, Ker-Gawl. "Lined Tritonia." (Irideae).

Geelong, Victoria, H. B. Williamson, Nov., 1910, No. 1430.

A native of South Africa, naturalised near Geelong.

XANTHIUM STRUMARIUM, L. "Cockle-burr." (Compositae).

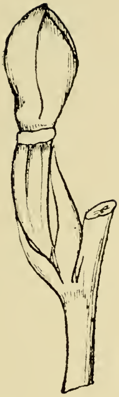
Dookie, Victoria, W. D. Wilson, Feb., 1911.

A cosmopolitan plant naturalised in New South Wales, and thence spreading to Victoria.

EXPLANATION OF PLATE XXIII.

THELYMITRA EPIPACTOIDES, F. v. M.

Fig. 1.—Bud.
2.—Front view of flower.



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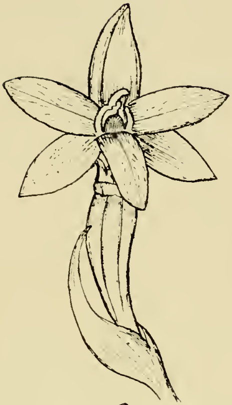

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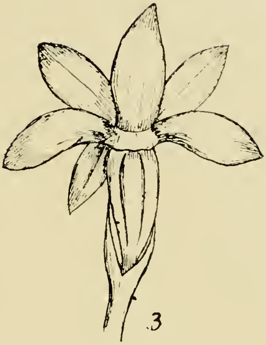

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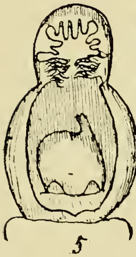

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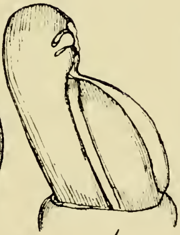

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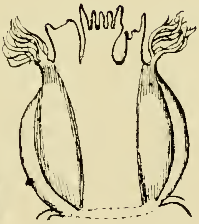

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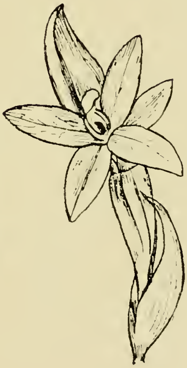

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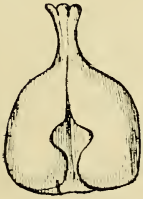

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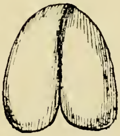

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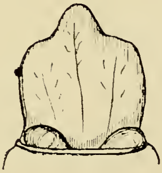

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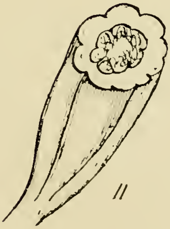

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Fig. 3.—Back view of flower.
4.—Lateral view of flower.
5.—Gynostemium.
6.—Side view of same.
7.—Gynostemium expanded, anther and stigma removed.
8.—Anther.
9.—Pollen masses.
10.—Stigma.
11.—Transverse section of fruit.
(All variously enlarged.)

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[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. VI.—*On a New Australian Genus of Phoridae Associated with Termites.*

By ARTHUR M. LEA.

(With Plate XXIV.).

[Read 8th June, 1911].

In September and October, 1910, I examined large numbers of nests of ants and termites in New South Wales; sometimes alone, at other times in company with entomological friends. On one excursion a minute apterous fly was obtained in a nest of termites. It belongs to the *Phoridae*,[1] and represents another of the highly remarkable genera of that family. The specimen was placed in a small tube, with two of the termites, without examination other than to see if it was a beetle, and it was not till after my return to Tasmania that its true nature was noticed. After the first careful examination it was replaced in the tube with alcohol, but this, unfortunately, evaporated, so that the accompanying drawing must be regarded as being made from a somewhat shrivelled specimen, as I am sure that the abdomen was considerably larger than as now figured.

Eutermiphora, n. g.

Head of moderate size. Eyes fairly large, irregularly subquadrate. Proboscis thin, rather long, geniculate near base, bifurcate at apex. Palpi thin. Antennae with first joint about as long as basal part of proboscis, second very short and concealed from some directions by third, third irregularly obpyriform, terminated by a setose arista. Thoracic segments entirely concealed from above. Wings and halteres absent. Abdomen with four segments of which the first is produced over the thorax and head like a hood. Legs rather stout; coxae prominent; femora about as long as proboscis; tibiae shorter; tarsi longer than femora, basal joint somewhat inflated.

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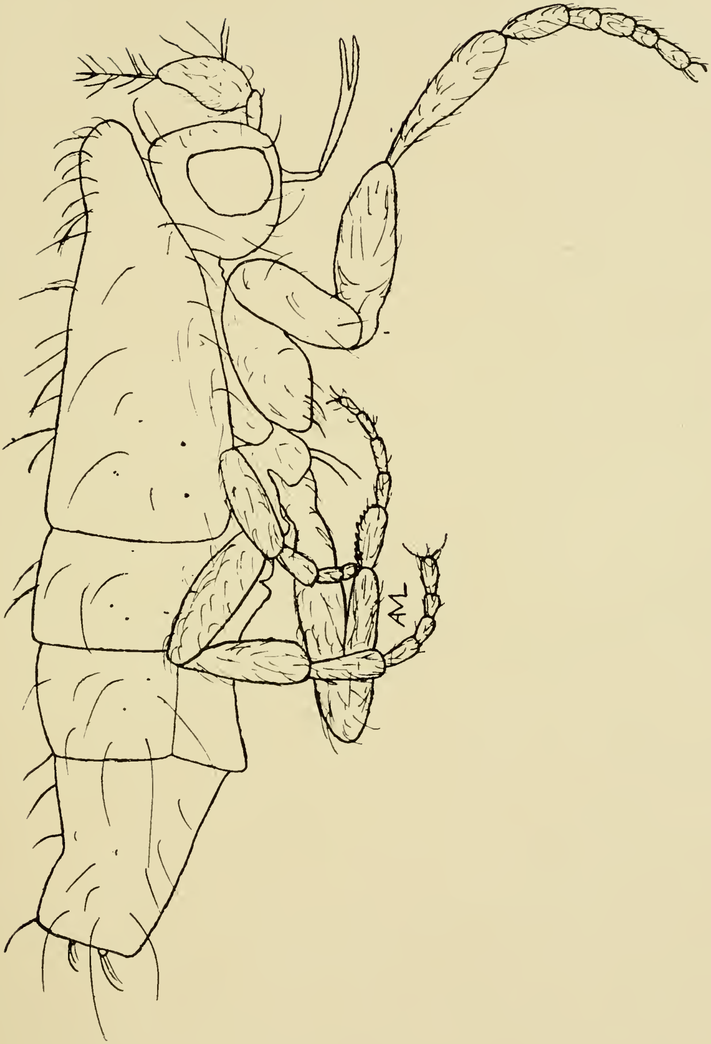
[1] This appears to be the first record of the family from Australia; a single winged Tasmanian specimen of it, however, was recently sent to Mr. Brues, who has described so many of the family.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In Brues' recent monograph of the *Phoridae*[1] the genus comes perhaps closest to *Termitoxenia*; but its thin, geniculated and bifurcated proboscis, with the curious abdomen, readily distinguish it from that, and from all other described genera. I have not ventured to risk destroying the specimen to be sure if ocelli are present, but believe them to be absent.

Eutermiphora abdominalis, n. sp.

♀ Pale brownish flavous, abdomen of a rather dingy white. With rather short pale pubescence on thorax and legs, becoming longer, sparser and darker on head and abdomen.

Head moderately transverse, angles rounded off; proboscis and palpi arising from a rather shallow depression. Thorax with only portions of sides visible. Abdomen large, surface very finely corrugated, first segment largest of all, produced over thorax and head in the form of a hollow hood, of which the apex is rounded, second and third combined slightly shorter than first, fourth diminishing in width to apex, which is truncate, within the apex two small setose projections. Length 1½ mm.

Hab.—New South Wales: Sydney, from a nest of *Eutermes fumipennis* (A. M. Lea).

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[1] In Wytsman's Genera Insectorum.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. VII.—*On the Displacement of the Optic Lobes during the Development of the Brain of the Fowl.*

By K. K. OLIVER

(Government Research Scholar, Biological Department, University of Melbourne).

(With Plates XXV.-XXXV.).

[Read 13th July, 1911].

In the following paper a series of drawings is presented which endeavours to illustrate clearly the manner in which the optic lobes of the common fowl, *Gallus domesticus*, form and change their position. The earliest drawing shows the mesencephalon as a single median structure on the dorsal surface, and the subsequent ones, its division into a bi-lobed structure, and its displacement caused by the development and growth both of the lobes themselves and of the adjacent parts. The later-stage drawings depict the lateral and ventral course of the optic lobes and their final attainment of the adult latero-ventral position. No attempts at histological work have been made, the morphological relationships alone having been considered.

The search through a very large number of memoirs dealing with the development of the brain has shown that the literature on this subject is concerned almost entirely with histological work, and I have been able to find very few references to the particular aspect of the work with which this paper deals.

A. Milnes Marshall in his "Vertebrate Embryology," p. 256, mentions the fact that the mesencephalon, till the end of the 4th day of incubation, remains approximately spherical, and on the 5th the optic lobes begin to form; also that on the 16th day the optic lobes begin to become pushed apart, and take up their adult position.

Frank R. Lillie, in "The Development of the Chick," mentions the formation of the optic lobes, but in connection with a detailed account of the rest of the brain only. A consecutive series of drawings, depicting the external formation and the descent of the optic lobes in relation to the adjacent parts of the brain, has apparently not been taken before—hence the present paper.

The drawings are divided into 10 sets of 6 each, and an eleventh set, showing the dorsal and lateral view of the adult brain for comparison with the foregoing figures. Each of the ten sets contains two solid drawings, that of the dorsal and lateral views respectively. There are also three sections taken transversely across the optic lobes—(1) across the anterior portion, (2) across the middle, and (3) across the posterior portion. The sixth drawing is a diagram of the lateral view of the brain, showing the approximate direction of the above three sections.

The solid drawings are taken under the camera lucida, and are as nearly as possible twice their real size. The sections are drawn under a Leitz camera lucida, and 1 × power, Leitz lens, and have been halved in reproduction.

The work has been carried on in the Biological Laboratory of the Melbourne University, and I should like to express my thanks to Professor Baldwin Spencer for assistance and advice, and to Messrs. J. Brake, A. O. V. Tymms and A. L. Rossiter for help in various ways.

Stage I. (Pl. XXV.)

The first stage corresponds approximately with the period of four days' incubation. At this point of development, the mesencephalon is represented by a very marked median dorsal swelling, which is usually said to correspond to the fourth and fifth neuromeres. A very slight groove (1b) beginning to form in the sagittal plane, and extending right along the dorsal surface of the mesencephalon, is the first indication of the division into the optic lobes. The epiphysis at this time is becoming prominent, and the cerebral hemispheres have assumed the dorsally recurved appearance characteristic of their earlier development.

In 1a, a lateral view of the brain is shown, with the eye forming. The epiphysis is seen in profile. The great distance between the small cerebral hemispheres, and the large mesencephalon is worth remark. Between the mesencephalon and metencephalon the isthmus is very distinctly marked. At this stage the line of axis of the mesencephalon and the metencephalon, and the line of axis of the cerebral hemispheres and the mesencephalon form an acute angle.

1c (Fig. 1, Section 1) shows a transverse section through the anterior portion of the mesencephalon. The walls of the mesencephalon are thin, and the lumen of the cranial cavity great in comparison with the thickness of the cranial wall.

1d (Fig. 1, Section 2) shows a transverse section through the centre of the mesencephalon and metencephalon. The section owes its apparently continuous shape to the fact that, because of the flexure of the brain, the section through the mesencephalon is transverse, and that through the metencephalon longitudinal.

1e (Fig. 1, Section 3) shows the posterior portion of the mesencephalon. The slight groove marking the beginning of the optic lobes is faintly indicated.

Stage II. (Pl. XXVI).

This stage corresponds approximately with the period of five days' incubation. At this stage the mesencephalon has become very definitely divided in the sagittal plane, the groove shown in stage I. having deepened in such a way as to indicate the outlines of the optic lobes. Although further development has taken place, these have not increased in size as much as the cerebral hemispheres, which are now assuming a definite form, and are enlarging considerably. This growth brings the cerebral hemispheres further back, towards the optic lobes, but there is a distinct space still between them.

The dorsal view (2b) shows the clear division of the mesencephalon into the two optic lobes, so that now, from being single and median, the mesencephalon has become a paired lateral structure, which is still very prominent on the dorsal surface. The cerebral hemispheres have increased in size at a rate which is out of proportion to the rate of growth of the optic lobes, which, though undergoing further development, have not materially enlarged since the preceding stage. The epiphysis is still well marked, though the diencephalon is now becoming relatively smaller than either the telencephalon or the mesencephalon. The first traces of the future cerebellum are not visible from the dorsal aspect, the swelling of the optic lobes posteriorly preventing this.

In the lateral view (2a) the rounded, more or less definite form of the cerebral hemispheres is seen beginning to encroach on the diencephalon from the anterior end, while at the same time the optic lobes are beginning to overgrow it from the posterior. The epiphysis is very definite on the dorsal surface, and the optic chiasm infundibulum are beginning to appear ventrally. The metencephalon, showing traces of the upwards and outwards growth which later form the cerebellum, is visible below the optic lobes. The angle formed by the axes of the telencephalon, diencephalon and mesencephalon, and of the mesencephalon, metencephalon and myelencephalon, is still rather less than a right angle, but is not so acute as in stage I.

2c (Fig. 2, Section 1) is a transverse section across the anterior part of the optic lobes. The lobes are now seen to be lateral in position, and the walls are becoming slightly thicker, while the optocoele is beginning to become smaller.

In 2d (Fig. 2, Section 2) a section is taken across the middle of the optic lobes, the cranial flexure still being so great as to cause the metencephalon and myelencephalon to appear as a longitudinal section.

2e (Fig. 2, Section 3) cuts through the posterior portion of the optic lobes, and the first beginnings of the cerebellum.

Stage III. (Pl. XXVII.)

The third stage corresponds approximately to a period of nine days' incubation. The mesencephalon is now divided into two rounded, dorso-laterally placed structures, which are from this time on called the optic lobes. They are still very large, comparatively, and form the most prominent portion of the brain. By this time the shape of the cerebral hemispheres has become quite definite and characteristic, and the olfactory nerve has begun to become apparent at the anterior end.

In 3b the cerebral hemispheres can be seen to be becoming elongated, and are stretching backward to meet the forward growing optic lobes. The epiphysis is prominent in the space still existing between the two pairs of structures, which is all that is visible of the diencephalon from the dorsal aspect. The forming cerebellum is hidden by the backward growth of the optic lobes.

In 3a the approximation of the cerebral hemispheres to the optic lobes is very marked in comparison with the preceding stage. From the lateral position the only part of the diencephalon visible is the epiphysis on the dorsal, and the infundibulum and optic chiasma on the ventral surface. The ventrolateral depression, caused by their position against the back of the orbit, is now becoming visible in the cerebral hemispheres, and the olfactory nerve is also to be seen forming. The optic lobes have grown forward in such a way as to overshadow the diencephalon from behind and the metencephalon from above. The lateral enlargement of the metencephalon, marking the commencement of the cerebellum, is becoming more clearly indicated.

3c is a transverse section in the plane indicated in Fig. 3, Section 1. It shows the increase of the brain substance over the preceding stage, and the thickening of the walls of the optic lobes.

In 3d the lateral position of the optic lobes is very definite. The crura cerebri are faintly indicated at this stage.

3e is a transverse section across the hinder part of the optic lobes, and just touches the myelencephalon longitudinally.

The axis of the cerebral hemispheres and the optic lobes, and that of the optic lobes and the metencephalon and myelencephalon have now altered, so as to become approximately at right angles to one another.

Stage IV. (Pl. XXVIII.)

The fourth stage corresponds approximately with a period of 10 days' incubation. In the dorsal view (4b) the cerebral hemispheres can be seen as elongated, closely opposed structures. Laterally they have encroached on the diencephalon in such a way as to hide it except at the median dorsal surface. The epiphysis is distinctly visible in the centre of this space. The optic lobes have encroached on the diencephalon, so that now they are closely approximated to the cerebral hemispheres. The pressure between the two portions of the brain is such that the optic lobes are beginning to be pushed out laterally, and their axis in the longitudinal vertical plane tends to become placed obliquely to that of the cerebral hemispheres and diencephalon in the same plane. The outgrowth of the metencephalon, to form the cerebellum, is now becoming visible between the posterior portions of the optic lobes.

In 4a the backward growth of the cerebral hemispheres and the forward growth of the optic lobes, so as to be in close approximation with each other, is clearly indicated. The optic chiasma and the infundibulum are distinct, and the ventrolateral depression of the cerebral hemispheres, caused by the formation of the floor of the orbit, is becoming more clearly marked. The epiphysis, still comparatively large, is seen in profile. The rotation of the axis of the optic lobes is not so easily discernible in the lateral view. The fold of the metencephalon, destined to become the cerebellum, is assuming a more definite shape, and the angle formed by the axis of the cerebral hemispheres and the optic lobes in longitudinal horizontal plane, and the axis of the optic lobes, and metencephalon, and myelencephalon in the same plane, is becoming much more obtuse, it now being somewhat less than a right angle.

4c (Fig. 1, Section 1) is taken across the anterior part of the optic lobes, and includes the epiphysis on the dorsal surface, and the metencephalon and myelencephalon in the longitudinal section.

The walls of the optic lobes are becoming much thicker now, and the histological structure is commencing to be differentiated.

4d (Fig. 4, Section 2) is a section across the centre of the optic lobes.

The crura cerebri are more definite than in the preceding figures, and the myelencephalon is seen in longitudinal section.

4e (Fig. 4, Section 3) shows the posterior portion of the optic lobes in section. They are thicker-walled than in the preceding stage, and their histological structure is more definite.

Stage V. (Pl. XXIX.)

The fifth stage corresponds approximately to a period of twelve days' incubation.

On viewing the specimen dorsally (5b) marked changes will be seen to have taken place since the last stage. The anterior portions of the cerebral hemispheres are now more closely opposed to each other than are the posterior parts. The optic lobes are becoming so rotated that their longitudinal vertical axes are almost at right angles to the axis of the cerebral hemispheres. The cerebral hemispheres are beginning to rise up dorsally, so that they overshadow the diencephalon and the epiphysis somewhat, and the pressure exerted on the optic lobes by them is beginning to force the optic lobes apart. Dorsally, the optic lobes are still prominent, but not so much so as at the preceding stages. So far it has been rather that the surrounding parts have grown up to the level of the optic lobes, than that they themselves have grown down, but from this stage on, the optic lobes descend steadily, presumably owing to the pressure brought to bear on them anteriorly by the cerebral hemispheres first, and then, later, posteriorly by the dorsal development of the cerebellum. The cerebellum at this stage has become distinctly indicated, and is beginning to assume its typical convoluted appearance. The dorso-lateral growth of the metencephalon has increased in such a manner as to begin to curl over on itself towards the myelencephalon, while on the dorsal surface of this area there are some six faintly marked convolutions appearing. The myelencephalon at this stage is also beginning to assume the characteristic appearance of the medulla oblongata, and both cerebellum and medulla are clearly seen from the dorsal aspect, the cranial flexure having changed so that the axes of fore, mid and hind brain now lie along approxiately the same straight line.

The lateral view (5a) shows a distinct change in shape. The diencephalon is now completely hidden by the pushing out of the optic lobes to the sides. The change in the direction of the axes of the lobes is much more clearly seen at this stage than at the preceding one. The epiphysis is hidden by the growth of the cerebral hemispheres on either side, and the optic chiasma and infundibulum are less distinct. The ventro-lateral depressions of the cerebral hemispheres are at this stage very distinct, there being a hemispherical concavity on each side of this portion of the brain. The characteristic backwards curling cerebellum, with its faintly marked convolutions, is a marked feature of this stage, and the long axes of the fore, mid and hind brain now lie in the same general direction.

In 5c (Fig. 5, Section 1) the increase of amount of the brain substance is worthy of remark. The section is purely transverse now, the change in the direction of the axis of the medulla eliminating the necessity of cutting it longitudinally.

5d (Fig. 5, Section 2) shows the lobes at about the centre. The crura cerebri are very distinct now, and are beginning to fill a considerable portion of the cavity of the optocoele.

A section across the posterior portion of the lobes in 5e (Fig. 5, Section 3) shows the increased thickness of the walls at this stage.

Stage VI. (Pl. XXX.)

The sixth stage corresponds approximately to the period of thirteen days' incubation.

The dorsal view shows little change since the last stage. The cerebral hemispheres are becoming rather fuller and more rounded in appearance, and are now well developed on the dorsal surface. The epiphysis is distinct in the space between the cerebral hemispheres and the optic lobes. The optic lobes themselves are beginning to become more decidedly flattened antero-dorsally, and have the appearance of being squeezed between the cerebral hemispheres and the cerebellum in such a way as to force the lobes down to a lateral and ventral position, so that the greatest breadth of the brain is now that across the optic lobes, and their long axis is at right angles to that of the cerebral hemispheres and the cerebellum. The cerebellum has developed considerably, and is now definitely convoluted, and the flocculi are commencing to be formed laterally. The myelencephalon has assumed the definite form of the medulla oblongata.

In the lateral view (6a) the curved surface of the cerebral hemispheres can be seen to have become more prominent dorsally than the optic lobes, which are now so far pushed laterally and ventrally that the chiasma and infundibulum are scarcely seen. The lobes have assumed a definite oval shape at this stage. The cerebellum has developed considerably, there now being eight convolutions visible from the lateral aspect. The flocculi, too, are taking definite form, while the medulla has increased in size, and is in proportion to the rest of the brain.

6c (Fig. 6, Section 1) shows the most anterior portion of the optic lobes, but so far forward that there is no optocoele included, and ventrally the chiasma has been cut through.

In 6d (Fig. 6, Section 2) a section about the centre of the lobes is given, showing the connection of the optocoele with the other brain cavities.

6e (Fig. 6, Section 3) cuts through the posterior portion of the optic lobes and the anterior convolution of the cerebellum.

Stage VII. (Plate XXXI.)

The seventh stage corresponds approximately to a period of 14 days' incubation.

In dorsal aspect the cerebral hemispheres are seen to have become roughly triangular, and are increasing in size at a proportionately greater rate than the optic lobes (7b). The epiphysis is now closely surrounded by the cerebral hemispheres anteriorly, and the optic lobes posteriorly. The optic lobes have quite lost their dorsal prominence, and are now lateral structures. The cerebellum has increased greatly both in size and in the definite formation of its convolutions, there being now eight definite convolutions visible on the dorsal aspect. The ninth, and originally the most posterior convolution, is hidden underneath the one anterior to it, in earlier development, though now, through the curling back of the cerebellum, posteriorly placed. The medulla is much as in the last stage, but the development of the cerebellum has partially hidden it.

In 7a the cerebral hemispheres can be seen to be becoming more developed. The ventro-lateral depressions are clearly marked. The optic lobes have altered but little since the preceding stage; they have sunk slightly towards the ventral surface. The cerebellum has become enlarged, and is now the most prominent feature of the brain dorsally. Nine convolutions are visible from this view, and the flocculi are becoming distinctly marked. The medulla remains much as at stage VI.

7c (Fig. 7, Section 1) is taken from the most anterior portion of the optic lobes. On the dorsal surface the epiphysis is cut through, and on the ventral the optic chiasma is seen. The walls of the lobes only are seen, for the section is anterior to the optocoele.

7d (Fig. 7, Section 2) shows a section at about the centre of the lobes. The brain substance is rapidly increasing in such a manner as to tend to fill the cavity of the optic lobes, so that the optocoele is now becoming much diminished in size. The crura cerebri are well developed.

In 7e (Fig. 7, Section 3) the posterior portion of the optic lobes, with the posterior portion of the optocoele, is seen. The cerebellum has assumed a very characteristic and definite shape and position by this time.

Stage VIII. Pl. XXXII.)

The eighth stage corresponds approximately to a period of 16 days' incubation.

In the dorsal view the cerebral hemispheres are seen to have become more triangular in shape than in the preceding stage. The cerebellum is growing forward so as to reach the posterior region of the cerebral hemispheres, and is overshadowing the epiphysis posteriorly, while the quickly enlarging cerebral hemispheres are beginning to hide it somewhat anteriorly. Eight distinct convolutions can be seen in the cerebellum at this stage, and the flocculi are becoming steadily more definite. The optic lobes are now most distinctly becoming overgrown and pushed down by the cerebral hemispheres and cerebellum, and are moving out and down to their final ventro-lateral position. The medulla is much as in the preceding stage.

The lateral view (8a) shows how very prominent the cerebellum has by this time become. Nine distinct convolutions are visible, and the flocculi are more distinct. The cerebral hemispheres are now above the optic lobes on the dorsal surface, and the optic lobes are moving down in a more or less directly dorso-ventral line. The ventro-lateral depressions of the cerebral hemispheres are becoming somewhat less distinct. The medulla is much the same as in stage VIII.

8c (Fig. 8, Section 3) is taken across the most anterior part of the optic lobes, the cavity of which is seen to be fast becoming filled by the growth of the brain substance composing its walls. The anterior lobe of the cerebellum can be seen in the median line, having by this time grown forwards and upwards until it is most prominent dorsally.

8d (Fig. 8, Section 2) shows a section across the middle of the optic lobes. The cerebellum can be seen to have assumed a prominent dorsal position in the sagittal plane. The optic lobes are sinking lower.

8e (Fig. 8, Section 1) is a section across the posterior part of the optic lobes, at the spot where the optocoele is almost obliterated. The cerebellum is beginning to assume its relatively large adult size.

Stage IX. (Pl. XXXIII.)

The ninth stage corresponds approximately to a period of eighteen days' incubation.

Dorsally there is very little change from the preceding stage to be seen. The cerebral hemispheres have increased slightly in size, and overhang the optic lobes on the dorsal surface rather more than in the previous stage. The cerebellum is enlarging still, and now shows nine convolutions from this view; the flocculi have become definitely established, and are now a characteristic feature of the brain. The epiphysis is comparatively insignificant in size, though a distinct structure. The most anterior portion of the cerebellum has grown forward in such a way as to meet the posterior portions of the cerebral hemispheres, and the optic lobes are clearly seen to have become pushed out laterally, and pressed down ventrally.

In the lateral view the optic lobes will be seen to have descended considerably; they are moving forward ventrally as well as downwards. The cerebellum is well developed on the dorsal surface, and is approximated to the cerebral hemispheres, which are still growing back posteriorly. Ten convolutions are apparent in the lateral view. The ventro-lateral depressions of the cerebral hemispheres are becoming less marked. The medulla is much as at the preceding stage.

9c (Fig. 9, Section 1) is taken across the anterior portion of the optic lobes in such a way as to show the optocoele, now rendered crescent-shaped and much smaller by the great increase in the brain substance. Above the optic lobes is seen the hinder portion of the cerebral hemispheres, now growing over the optic lobes from before back, and tending to hide them from view dorsally. The epiphysis is visible in the mid-dorsal line of this figure.

9d (Fig. 9, Section 2) is a section across the centre of the region of the optic lobes. It shows a marked increase in the size of the cerebellum, together with the decidedly lateral position now assumed by the optic lobes.

9e (Fig. 9, Section 3) is a cut across the posterior part of the region of the optic lobes. It shows the most posterior portion of the optic lobes, the cavity of which is not seen, the section being taken so far back as to cut through the brain substance only. The cerebellum is very definite in the mid-dorsal line, and has assumed almost adult proportions,

Stage X. (Pl. XXXIV.)

The tenth stage corresponds approximately with a period of 20 days' incubation.

In the dorsal aspect (10b) there will be seen a marked difference in the size of the brain. The cerebral hemispheres are overshadowing the optic lobes very markedly from the anterior, and the cerebellum is also growing over them from the middle outwards. The optic lobes can now scarcely be called latero-dorsal structures, but rather latero-ventral. In the cerebellum nine well-developed convolutions are visible, and the flocculi are well marked. The epiphysis, though still present, is now but faintly seen, and is sunk in between the posterior portions of the cerebral hemispheres and the anterior part of the cerebellum.

Laterally (10a) the cerebral hemispheres are seen clearly to be growing over the optic lobes, from the anterior posteriorly, and from the dorsal surface ventrally. The approximation of the cerebellum and the cerebral hemispheres has squeezed the optic lobes in such a manner as to cause their greatest development to take place ventrally, so that now the structures can be seen to have become definitely ventro-lateral. The cerebellum has eleven convolutions visible in this view, and the flocculi have assumed the characteristic appearance found in the hatched bird. The ventro-lateral depressions of the cerebral hemispheres have become so faint as to be scarcely visible. The medulla is much the same as in the previous stage.

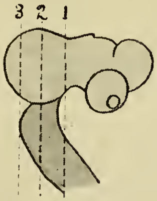
10c (Fig. 10, Section 1) shows a cut through the fore part of the optic lobes, at the place at which the optocoele extends furthest anteriorly. The chiasma is indicated ventrally, and the most anterior convolutions of the cerebellum are shown. Dorsal to the optic lobes in this section, the most posterior portions of the cerebral hemispheres appear, so relegating the optic lobes to a very definitely ventro-lateral position.

In 10d (Fig. 10, Section 2) a section across the middle of the optic lobes is given. The cerebellum is distinct in the centre dorsally, and the optic lobes themselves are seen in a ventral and lateral position. The optocoele is now to a great extent obliterated by the great increase in size of the crura cerebri, and assumes a roughly hemispherical shape in transverse section.

In 10e (Fig. 10, Section 3), the enormous development of the cerebellum is visible, taking up practically all the dorsal surface in the section, and the optic lobes are most distinctly seen to be lateral and ventral in position; the optocoele is not seen at all in this section.

The Adult Brain. (Pl. XXXV.)

The adult brain is inserted merely for comparison. I have not worked it at all, so can give no description of it.



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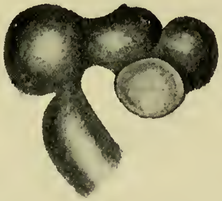

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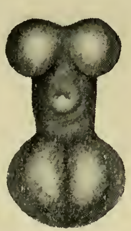

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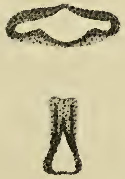

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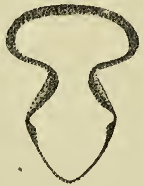

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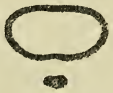

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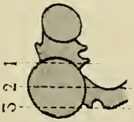

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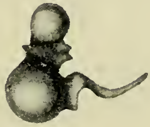

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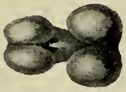

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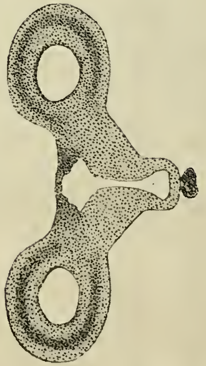

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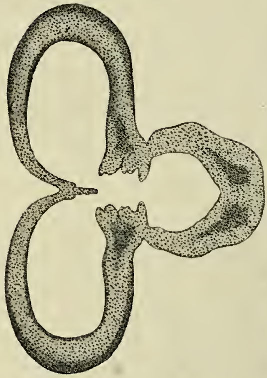

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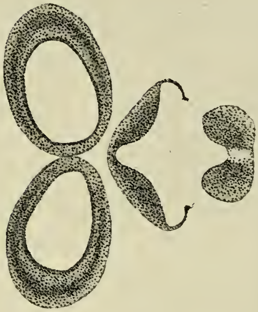

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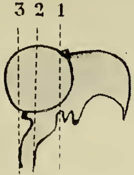

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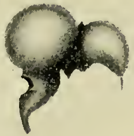

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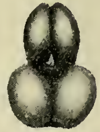

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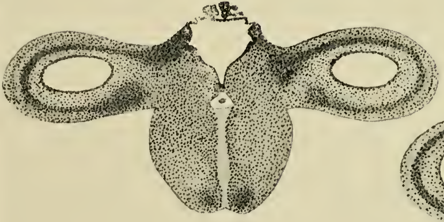

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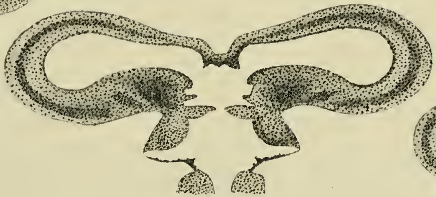

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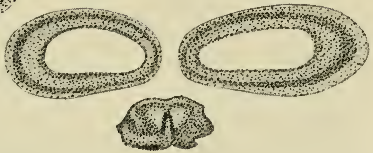

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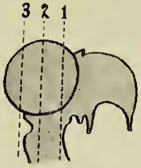

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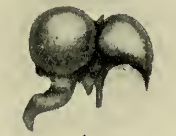

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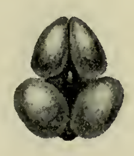

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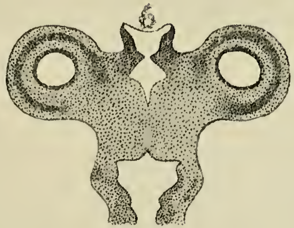

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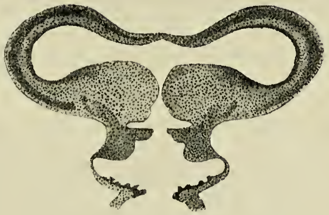

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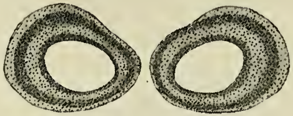

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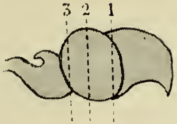

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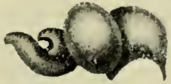

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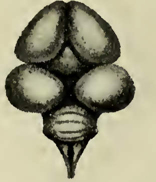

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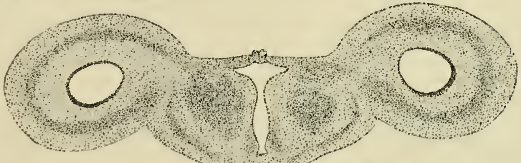

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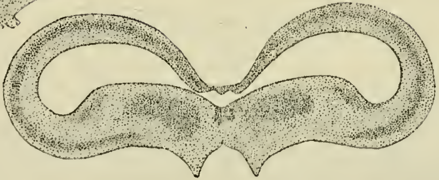

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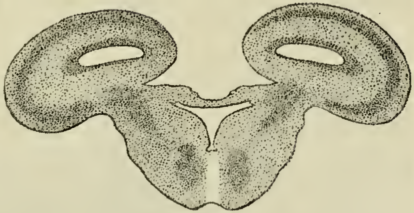

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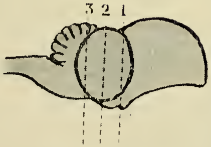

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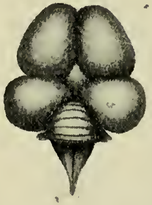

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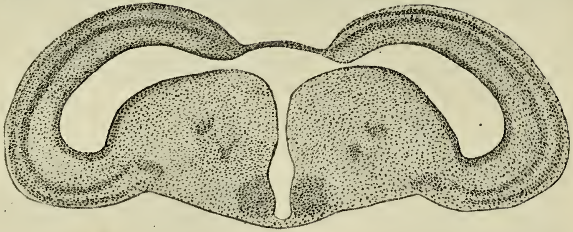

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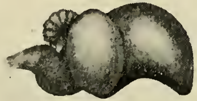

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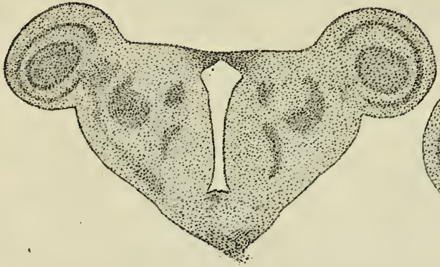

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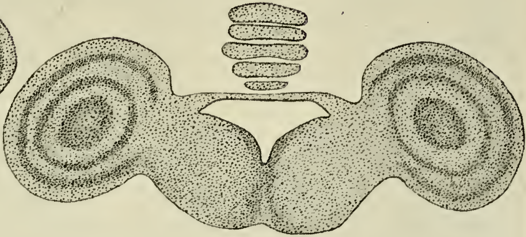

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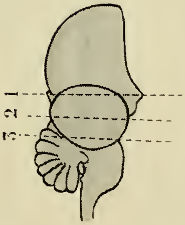

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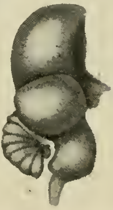

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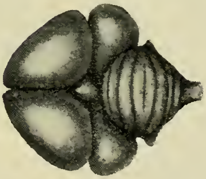

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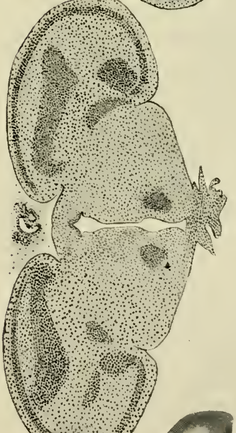

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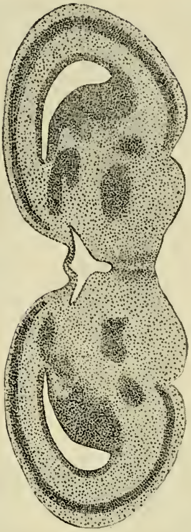

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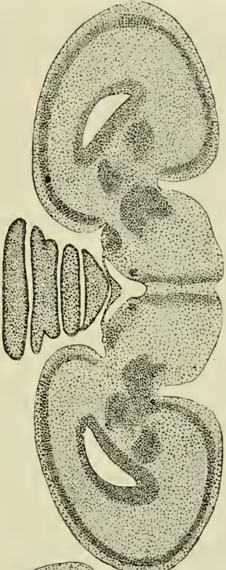

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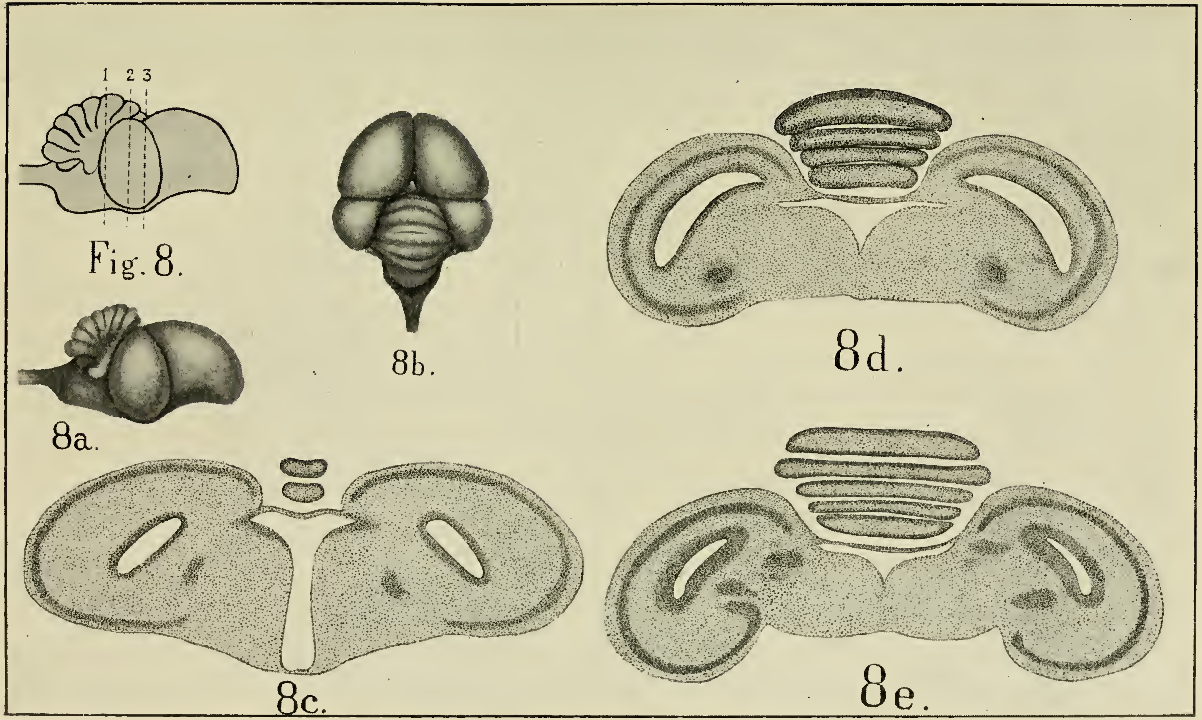

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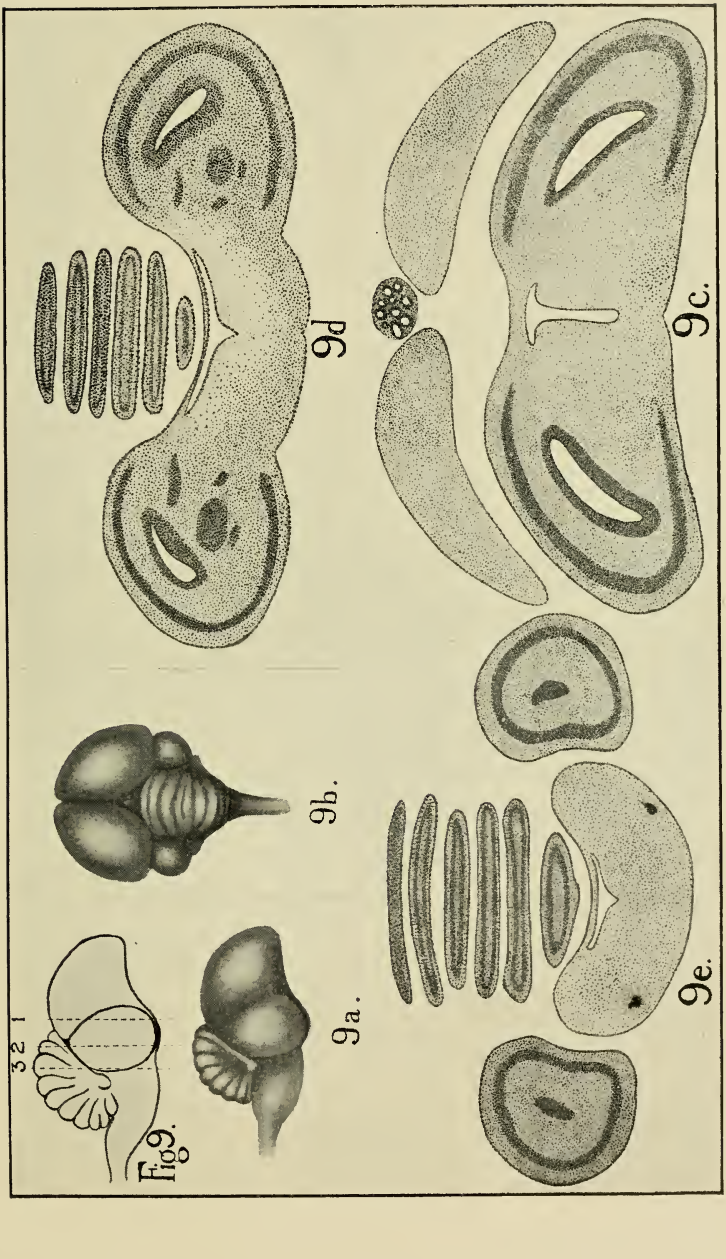
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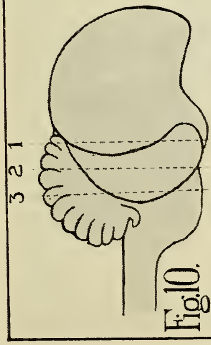

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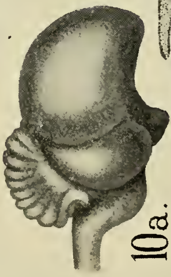

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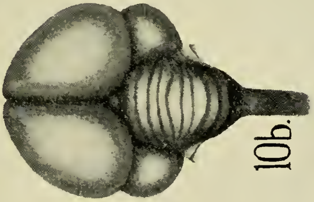

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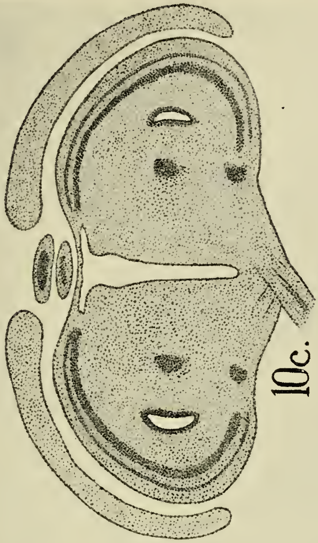

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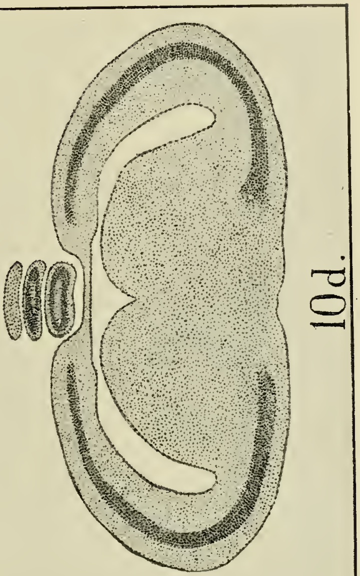

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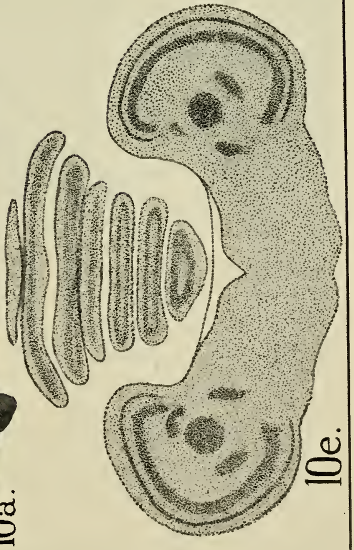

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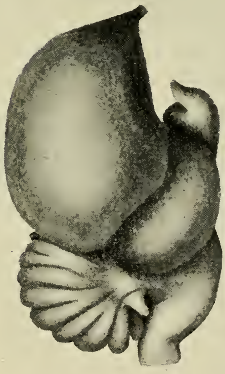

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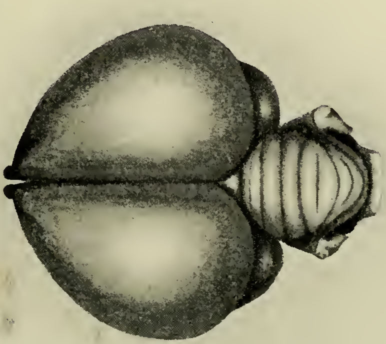

11b.

DESCRIPTION OF PLATES XXV.–XXXV.

Figs. 1-10 are diagrams of the brain, lateral view, to show the directions of sections 1c-10c, 1d-10d and 1e-10e.

1b-11b are drawings of the dorsal surface of the brain. They are twice natural size, except in 1b, where the brain was drawn under a Leitz microscope with a 1 × objective and No. 2 eye-piece and halved in reproduction.

1a-11a are drawings of the lateral aspect of the brain. They are twice natural size, with the exception of 1a, which is reproduced under the same conditions as 1b.

1c-10c, 1d-10d and 1e-10e are sections cut in the direction indicated in Figs. 1-10. They are all drawn under a Leitz microscope with a 1 × objective and a Leitz camera lucida, and halved in reproduction.

[Proc. Roy. Soc. Victoria, 24 (N.S.). Pt. I., 1911.]

Art. VIII.—*The Origin of Cuts on Bones of Australian Extinct Marsupials*

By BALDWIN SPENCER, C.M.G., M.A., F.R.S.,
Hon. Director, National Museum, Melbourne,

AND

R. H. WALCOTT, F.G.S.,
Curator of the Geological and Ethnological Collections, National Museum.

(With Plates XXXVI.-XXXIX.).

[Read 11th May. 1911].

In this paper we propose to deal with a series of bones showing cuts and incisions of various descriptions, our main object being to discuss the agency or agencies responsible for the production of these cuts and incisions. The bones have been derived from three different localities in Victoria—viz., (1) Perjark Marsh, (2) Buchan, (3) Lake Colongulac.

1.—The Pejark Bones.

The specimens from this locality were obtained during a special search made on behalf of the National Museum, Melbourne, in December, 1909, in the hope of securing additional evidence of the antiquity of man in Victoria, Mr. A. J. Merry, of Terang, some time previously having discovered under the volcanic tuff at that place an aboriginal stone implement,[1] together with fragments of bone, which he generously presented to the Museum.

Before dealing with the bones themselves, it will be well to give an account of the deposits of Pejark Marsh. This is rendered more necessary, as hitherto little was known concerning the relationship of the various associated beds, the nature of the bone bed itself, and the mode of occurrence of the bones in the various localities in the south-west part of Victoria where mammalian remains have been found.

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[1] This discovery has not yet been described.

Pejark Marsh, which is of some considerable extent, occupies a slightly depressed area of country lying mostly to the east of the road running due north from Terang township to Mount Noorat, in the county of Hampden, and was, it is said, originally covered with a thick growth of tea-tree scrub and eucalypts. A channel was made about twenty years ago to drain the Marsh, and the water is carried by a culvert under the Noorat road at a point just about a mile distant from the Terang post office. It was here and at several places for a quarter of a mile along the channel to the west that our excavations were made. Near the culvert a shaft showed some three feet of heavy black alluvial soil, eighteen inches of volcanic tuff, and five feet of black clay, passing into a yellow clay. The black clay is not clearly defined from the underlying yellow clay, but blends into it, unlike the volcanic tuff, which is sharply marked off from the soil above and the black clay below, and stands out like a ledge in parts of the drain where the clay has fallen away from beneath it.

Just at the junction of the two clays the majority of the bones occurred, including all the larger pieces, for practically the whole of the specimens are fragmentary. About a quarter of a mile west of the culvert the black clay bed becomes thinner, and near the bottom of it, and apparently immediately over the yellow clay, a black nodular cement makes its appearance; and just above it, in its surface layer, were a few fragments of bones, blackened by manganese oxide where they had been enclosed in the cement. In the excavations near the culvert the proximity of the yellow clay was generally indicated by the presence of a few hardish, brown, ironstone nodules. At a depth of three and a-half feet in the yellow clay, and about thirteen feet from the surface, the clay became harder, and red in colour. Sinking then became too difficult, on account of water, and a crowbar was driven down in the bottom of the cut.

At three feet the bar entered a softer stratum, from which water freely flowed through the hole made by the bar, showing that the water-bearing bed from which the residents obtain their supplies had been pierced. What that bed consists of could, therefore, not be ascertained, but, presumably, it is the soft fossiliferous limestone seen along the shores of Lake Keilambete, situated some two and a-half miles to the west, and which belongs to the marine tertiary series underlying the greater part of the volcanic areas of the Western District of Victoria. The black clay occurring under the tuff is highly carbonaceous, and this character, together with the frequent occurrence of what seem to be root cavities lined with a thin and hard ferruginous casing, and the constant presence of impressions of coarse grass-like leaves in the lowest layers of the tuff bed, denote the existence at a former period, as in historical times, of a swamp supporting a heavy growth of vegetation. In the upper part of the yellow clay are also seen fine black fibrous impressions left by the rootlets sent down by plants growing in the old swamp soil. The only foreign bodies found in the black clay besides the bone fragments were a few scattered quartz pebbles and a pebble of decomposed dolerite.

The tuff, or "sandstone," as it is invariably called locally, where measured, has a thickness varying from fifteen inches to two feet, and, as nearly as could be ascertained, occurs under a depth of from two to three feet of soil. It is calcareous, fine-grained, tough, and fairly even in its texture, but distinctly bedded. Its mineralogical character seems to be similar to the tuffs found elsewhere in the neighbourhood. In it were identified by Mr. F. Chapman, Palaeontologist to the National Museum, fresh-water diatoms, giving additional evidence that the tuff was laid down in an old swamp or lagoon; and still further palaeontological evidence was afforded of this fact by the discovery of the cast of a "yabbie" (*Engaeus sp.*) seemingly similar to those existing in the Pejark Marsh at the present day. Something may also be said about the yellow clay, as there are some points of interest in connection with it which may aid in determining its origin, and which, later, may be of use in correlating this bone bed with others in the district.

The first thing noticed was that the physical condition of this clay was quite different from that of the black clay above it. Instead of being tenacious and coming up in solid lumps, it broke into small pieces when dug into by the shovel. Again, it was not compact, but porous, and samples in drying showed a tendency to crack along indistinct lines of bedding. In the dry state it was very friable, and, on being placed in water, rapidly disintegrated.

After washing away the lighter clayey material, the residue—of which there was a fair quantity—consisted for the most part of quartz. By the naked eye a few black and bright-green particles could be picked out of the clay, and both these showed, the latter very sparingly, in the residues after washing. Among the black particles some were transparent and brown under the microscope, and could be referred to augite. Most of them, however, were quite opaque, with dull surface and glassy fracture. These appear to be a variety of spinel, probably pleonaste, and not picotite, as no chromium was detected. The bright-green particles are, no doubt, chrome-diopside, a mineral associated with the granular olivine, occurring as nuclei of volcanic bombs and as ejected blocks round some of our newer crater hills. Colourless zircons and a few grains of yellowish olivine are also present. The red patches found at a depth of about three feet or more in this clay have apparently been enriched in their iron contents by the leaching of the upper part of the bed, and the iron so introduced has taken the form of minute concretionary pellets of limonite. The general character of the clay and its contained minerals point strongly to it being a volcanic tuff, in all probability laid down on the tertiary rocks before the subsidence took place which created the depression now occupied by swamp lands.

The bones found at Pejark Marsh are, as mentioned, almost entirely of a fragmentary nature, only three or four toe bones being complete. They occurred principally just at the base of the black clay where it merges into the yellow clay below, while a few, but always very small in size, were scattered higher up in the former, a fact proving that they must have sunk through that part of the old swamp soil formed before the time of their deposition.

We were at first, more especially perhaps as the aboriginal implement was of the nature of an anvil or pounding stone, disposed to attribute to human agency the fragmentary condition of the bones forwarded by Mr. Merry; but further consideration and the securing of a larger collection have caused us to modify this opinion. We also thought that the place where the bones and implement were found was probably once the site of a camp by the side of a lagoon or marsh, but our investigations on the spot led us seriously to doubt this original surmise. In the first place the bones in the patches disclosed were not accompanied by the concomitants of an aboriginal camp, and, more important still, many of the fragments obtained showed unmistakable evidence of the fact that some powerful predatory animal had been at work on them.

The most striking feature in connection with them is the peculiar fragmentary nature of almost all the specimens, which vary in length from 12-170 mm., only one, however, attaining anything like the latter dimensions. Even such teeth as were found, were, with the few exceptions mentioned below, broken into small fragments and scattered through the clay.

Amongst the bones the only perfect specimens consist of two phalanges, but three others are nearly complete. Besides these, there are four more specimens sufficiently perfect to permit identification. They are all parts of metatarsals, two being the proximal ends of the fourth metatarsal of individuals of the genus *Macropus*, the larger agreeing in size with that of *M. titan*, and the smaller with those of our largest living kangaroos. One of the other two is the distal end of a fifth metatarsal of the size of that of *Palorchestes azael*, the other being somewhat smaller. All of the bones are mature. In addition to these, two molar and two incisor teeth of a small wombat were found, but not in direct association with other bones, and a claw bone remarkable for its large size and lateral compression. From the merest cursory examination it is obvious that the fragmentary condition of the specimens is not due to natural causes. If man had broken the bones to obtain the marrow—and there is no evidence to show that there could have been any other reason for his breaking them—three things would be noticed.

In the first place percussion marks would be present. Next, the bones would be completely broken up, more particularly longitudinally, to enable the marrow to be readily extracted. Lastly, only those which contained marrow would be treated in this manner.

In only one instance can any indications whatever be seen of marks which might be attributed to a natural stone or stone implement, such as would be used by the natives for bone-breaking. On one edge of the specimen referred to there is the appearance of its having received a blow which has struck off a fairly large conchoidal flake from the interior of the fragment. As this has taken place subsequently to the longitudinal fracturing of the bone, it could not have been made to get at the marrow. The bones certainly have been broken up very effectively, and in a longitudinal direction in nearly every instance, very few, not more than three or four specimens, being fractured in a transverse direction only. The longitudinal fracture, however, is not confined exclusively to bones and parts of bones containing marrow, for the solid distal end of a large femur (Plate XXXVI., Fig. 2) has been broken through quite apart from the shaft, and two small jaw bones (one of which is seen in Plate XXXVI., Fig. 14) are also cleanly split from end to end through the teeth sockets, which explains the fact that teeth, often themselves fractured, were met with, scattered through the clay bed. Fig. 13, Plate XXXVI., is the dorsal portion of the proximal phalanx of the fourth toe of a large extinct kangaroo. It has evidently been sundered lengthwise from a bone similar to Fig. 12, Plate XXXVI. Then, finally, there is the large fragment of a solid, massive bone (Fig. 1, Plate XXXVIII.) discovered by Mr. Merry close to the stone implement, broken longitudinally, approximately in half.

It appears certain that, in the case of the great majority of the specimens, the bones were not broken by human beings with the object of getting at the marrow, and we must therefore seek for some other explanation of the way in which they have been fractured.

Many of the bones give no clue at all as to how they were broken, but, on the other hand, there are, on certain of them, marks of such a nature that we think they could only have been made by the teeth of carnivorous animals; and this has led to the most serious doubts being entertained as to the human origin of any of the cuts or marks on the bones.

Mr. C. W. De Vis (6), in his paper, "On Tooth-marked Bones of Extinct Animals," says, "About five per cent. of some hundreds of bones from the Darling Downs awaiting examination, are pitted, scored, cracked, chopped and crushed by the teeth. They have in fragments passed with the faeces through the intestines of bone-eating beasts of prey. Fully eighty per cent. of the remainder tell, in this splintered fragmentary condition, the same tale of violence."

SURFACE INCISIONS AND CUTS.

On the greater number of specimens fine incisions and cuts of varying shape and length are scattered, sometimes thickly, all over the external surface of the bone. In many cases they convey the impression that the whole surface of the bone has been scratched by some sharp-edged or pointed implement. They vary in shape from a straight line to a curve similar to that of a boomerang. The short, straight, chisel-like incisions are, as a rule, terminated abruptly at one end, where the incision is deepest, as are also some of the longer ones. These short incisions are seen in specimen Fig. 2, Plate XXXVI., the fractured head of a femur, and several of them immediately adjoin and are parallel to the lines of fracture. In one or two cases they terminate in a slightly marked bifurcation.

The shallow surface incisions, as a general rule, occur in large numbers when they are present at all. In addition to these there are (Figs. 10, 11, Plate XXXVI.) more definite cuts, or gashes, of a V or wedge-shaped form in cross section, which have penetrated the bone to a greater depth than in the case of the ordinary incisions, but they are comparatively seldom met with. In some cases (as in Fig. 8, Plate XXXVI.) the cut has been made at such an angle that it has resulted in removing a slice from the bone surface.

CUTS PENETRATING THE BONE, AND RESULTING IN FRACTURE.

In the large collection of bones, every bone save two phalanges being in a fractured condition, there are a certain number of special interest, because the nature of their fractures affords, we believe, a clue to the way in which these were produced.

Some few of the bones (such as Figs. 12, 15, 16, Plate XXXVI.) have fractures displaying no features of such a nature as to suggest that they have been produced by any special agency. The tooth, for example, of any animal strong enough for the purpose, might have caused such a fracture as any one of these shows. On the other hand certain bones are fractured in such a definite way as to indicate that they have all been subjected to similar treatment by some special agency. A very good example is seen in Fig. 4, Plate XXXVII., which we may take as typical of the cuts with which we are now dealing. The fragment of bone measures 52 mm. in length, 17 mm. in width, and 6 mm. in thickness. It has been cut through longitudinally, as if by a pair of curved shears, the edge of the bone showing no broken fracture. The clean cut, which has a very characteristic form, slopes slightly, and its exact shape may be seen by reference to the figure. In some instances the original cut has been continued by a line of fracture along the length of the bone, as, for example, is probably the case on the right side of the Fig. 7, Plate XXXVII., and when this occurs it would be naturally impossible to say exactly where the cut ends and the fracture begins, more especially as most of the bones are slightly weathered. The cuts on Figs. 5, 6, Plate XXXVII., which are respectively 5 and 7 mm. in thickness, agree very closely indeed with the one above described (Fig. 4, Plate XXXVII.), and it is quite evident that they have all been made by the same agency.

In other bones—as for example, Figs. 8, 9, 10, Plate XXXVII., and many others—the edges of the bones show, not what appears to be one single cut, as in the first-mentioned specimen, but a considerable number, as many as nine in Fig. 8, Plate XXXVII. The cuts, in some instances, as in Fig. 10, Plate XXXVII., are so directed as to give the bone a pointed end. Other bones, as in Figs. 13, 14, 17, Plate XXXVII., have a terminal diagonal cut, producing again a pointed end. Fig. 12, Plate XXXVII., is of the same type, but evidence of three cuts is very plain. Fig. 14, Plate XXXVI., and Figs. 17, 18, 19, Plate XXXVII., show very characteristic concavities, as if the bone had been partly cut and then fractured along a curved line. The bone represented by Fig. 18, Plate XXXVII., shows an even and regular concavity on its inner side. On the outside, as seen in the figure, this concavity is confined to only half the thickness of the bone, the exterior half being broken into a large and more irregular curve. In Fig. 17, Plate XXXVII., the contour of the cavity is quite regular; one end has been fractured by a diagonal cut. Fig. 19, Plate XXXVII., has two concavities, one on each side of the bone, one slightly in advance of the other. The curves of these concavities are much smaller than in the other specimens; one, particularly, seems as if it had been formed by several blows or applications of some instrument, by which small pieces were broken out, leaving a somewhat jagged edge. From the deepest part of this concavity towards the pointed end of the specimen, the thin outside layer of the bone has been removed, and its margin is similarly defined by scallops. The shape of the pointed end is due to cuts.

Fig. 14, Plate XXXVI., is a longitudinal section of the left ramus of a kangaroo jaw.

ORIGIN OF THE INCISIONS AND CUTS.

In regard to the smaller incisions, it must be pointed out that, though these are such as to produce a general scratched appearance of the surface on which they occur, a large number of them cannot, strictly speaking, be called scratches, if by a scratch is meant an incision made by drawing a pointed implement, such as a needle or tooth, over some surface. Some of the fine markings may be due to scratches, but in many of them the incision, seen under a magnifying power, is not symmetrical, and conveys the idea of having been made by a cutting edge, sometimes of considerable length. Further, a very characteristic feature is that they are curved (in many instances boomerang shaped), whereas, if they were true scratches, they would more naturally approach a straight line in form. The question arises whether they have been produced naturally by attrition or artificially. That the former is not the case, their very irregular arrangement and almost uniformly curved shape seem to prove conclusively. We have, therefore, to search for some artificial agency, and since from their nature it is highly improbable that they were caused by man, the agency must be found in some other predatory animal.

It will suffice now to say that we believe this animal to have been *Thylacoleo*, the evidence in favour of which we will proceed to bring forward in connection with the discussion of the question of the origin of the larger cuts.

In many cases the fractures are of such a nature that they might have been produced by the teeth of any such strong predatory animal, as the *Dingo*, *Thylacine* or *Sarcophilus;* that is, leaving *Thylacoleo* out of the question, we have animals which lived in Victoria in those ancient times quite equal to the task of merely fracturing the bones. It is, however, in the bones showing cuts which, at first sight, would appear to be almost without doubt due to human agency, that interest centres. In regard to them it may be said at once that they have been made either by man or by the bone-eating *Thylacoleo carnifex*. No *Dingo*, *Thylacine* or *Sarcophilus* could possibly produce such cuts.

As far back as 1859, Owen (16) published his well-known memoir on *Thylacoleo*, in which the skull was described for the first time, and in which also the characteristic premolar was stated to be adapted for piercing, holding and lacerating, like the canine of a carnivore. Owen's conclusions as to the nature and affinities of *Thylacoleo* were stoutly contested by other workers, notably by Falconer (8), Flower (9), and Krefft (10), all of whom came to the conclusion that the animal was, in the main, a vegetable feeder, and that the great cutting premolar was simply an exaggerated form of the same tooth molar was simply an exaggerated form of the same tooth present in the herbivorous *Hypsiprymnus* (=*Potorous*), one of the so-called rat-kangaroos. At a later period Owen was supported by McCoy (14), De Vis (6), and Broome (2), and it is generally admitted now that he was right, and that *Thylacoleo* was carnivorous in its habits.

Mr. De Vis on three occasions has referred to the bone-cutting power of *Thylacoleo*. In 1883 (6) he published his paper —previously referred to—"On Tooth-marked Bones of Extinct Marsupials," describing the occurrence on Darling Downs of large numbers of bones that had been broken up by predatory animals, instancing especially one of *Macropus affinis*, which bore the mark of the teeth of *Thylacoleo*. In 1900 (4) he published a paper, "The Bones and Diet of *Thylacoleo*," in which he described and figured first the ulna of a large kangaroo with cuts upon it, in regard to the making of which he says, "The only two capable instruments known to me are the tomahawk and the tooth of *Thylacoleo*." He also figures other bones bearing the marks of some strong cutting object, and, amongst them, the mandible of a young kangaroo that "has been crushed inwards and downwards so that a deep and well-defined area of impression has been left, and that impression is a mould in the soft bone, of the surface of the tooth of a young *Thylacoleo*. On the inner side opposite to this is another impression, but shallower and with irregular vertical ridges and groovings, just as clearly produced by the opposite tooth of the same jaw."

Mr. De Vis (5) also deals with the bone-cutting capacity of *Thylacoleo* in connection with the cuts on what is usually known as the "Buninyong Bone."

We have already referred to man as a possible agent in shaping the bones. That a good reason for breaking the bones might be found in his desire to obtain the marrow from them is apparent, and many bones in the collection favour this view, but the process is such a simple one that it is unlikely a sharp edged cutting implement, presumably made of stone, would be employed. Even if it were brought into requisition the force sufficient to produce cuts of the kind under consideration by one or two heavy blows with a stone axe, having what would be to us a blunt edge, would, almost certainly, simply smash the bone, leaving the only evidence of the nature of the implement used in the form of a surface cut along the line of fracture. Besides this, heavy blows from a straight-edged stone axe could not possibly have cut out the characteristic curves illustrated in Fig. 4, Plate XXXVII. That curves could be cut out by an axe by continuous and careful chipping is quite within the range of probability, but Fig. 8, Plate XXXVI., and Fig. 1, Plate XXXVII., give very good reason for believing that chipping in the manner adopted by man with a stone implement had not been resorted to. In these we have the most interesting of all the specimens, for they afford unquestionable evidence that the bones have been cut, and neither chipped nor ground, and, if this be so, we may reasonably conclude that the cutting through out has been executed by the one agent and by the same means. The importance, therefore, of discovering the maker of the cuts in these two specimens is obvious, for in it lies the solution of the whole problem. To take Fig. 8, Plate XXXVI., first—a small fragment of a large limb bone, about 15 mm. from its broad end, on its outer and convex surface, a roughly crescent-shaped shallow gash is present. Its length is about 12 mm. From the gash, for a width of 6 mm., a slightly concave slice has been pared from the surface of the bone to the termination of the broad end. There is no mistaking the interpretation of the evidence. The instrument with which the cut was made must have closed on the bone at a very low angle, and then part of the cutting edge skidded along the surface, taking with it a thin slice of the bone. Fig. 1, Plate XXXVII., brings us nearer the curved cuts seen on some of the described specimens, and it may be regarded as an intermediate stage between those specimens and Fig. 8, Plate XXXVI., just dealt with. We see in this example the work of the same instrument, only it has here cut the bone at a much more upright angle, and, consequently, a curved incision, 4 mm. in width, has been made across one corner of the bone to a depth of between 2 and 3 mm. The severance of the corner from the main part of the bone by a continuance of the cut would have yielded a form almost identical with Fig. 2, Plate XXXVII., in which a similar cut had passed obliquely through the bone. The evidence is conclusive that the bones have been operated on by some object capable of making a clean cut through as much as 7 mm. of solid bone, and we know of no implement possessed by the Australian aborigine with which this could be done. For the purpose of obtaining the marrow, man would most certainly smash the bones in the easiest way possible, as he does at the present day, and, apart from this, it is difficult to surmise what object led him to make these cuts, supposing he did so, for they fail to reveal any evidence that they were formed during the process of manufacture of any implement, weapon or personal ornament.

We therefore conclude that there is no evidence indicative of the fact that man took any part whatever in the creation of the remarkable cuts under discussion.

On the other hand, the information gained by a study of the whole of the specimens at our disposal tends strongly to support the conclusion that the work in question is that of a bone-eating animal, but it must be conceded that his jaws were immensely powerful, and his teeth capable of making cuts of a form that might well create a feeling of scepticism in regard to the existence of such a creature. As *Thylacoleo* is the only animal known possessing teeth anything approaching the description required, we have experimented with the idea of ascertaining whether it is possible to imitate the diversity of cuts and markings on the various described specimens, with the aid of the teeth of that beast. In this way, using modelling clay to represent the bones, we found that all those surface scorings which are sufficiently defined for us to be sure of their artificial origin could be duplicated by pressing different parts of the cutting edges of the teeth lightly on the clay. The chisel-like incisions, shown particularly in Fig. 2, Plate XXXVI., have their abrupt terminal ends very slightly bifurcated, and this feature was remarkably imitated—more prominently on account of the medium used—by the edge of the upper tooth, just where the anterior end commences its terminal curve.

If the great premolar were biting on a flat surface only two indentations would be made, one corresponding to each of the raised ends of the cutting ridges, but, on the curved surface of the bone in question, the whole, or at least the greater part, of the cutting ridge came into play, with the result that the surface of the bone is marked by long curved incisions.

Mention may be made of the scalloping very inadequately shown on Fig. 8, Plate XXXVI., and Figs. 1, 19, Plate XXXVII., to which reference has already been made in regard to Fig. 19, Plate XXXVII. On one corner of Fig. 1, Plate XXXVII., there are three tiers or steps of scallops made by cuts similar in form to the slight incisions on the surface of this and other bones—(indeed one of the chisel-like incisions is present on one of the steps)—but cutting more deeply into the bone substance. In other words, we have a series of cuts all of similar form, the slightest resulting in mere surface markings, others in more or less deep scalloping, and others, finally, in complete cuts through the bone.

Before passing on to make some general remarks, we may draw attention to one or two other specimens. The deeper straight impressions or gashes as seen in Figs. 10, 11, Plate XXXVI., although comparatively few in number on the Pejark specimens, are common on those from elsewhere to which we shall have occasion to refer later. In both specimens such gashes have apparently been the means of fracturing the bones at oblique angles These cuts may be compared with those figured by De Vis (4), to one or two of which they are closely comparable. They are attributed by that author to the agency of *Thylacoleo.*

Some fragments show clear evidence of having been chewed after having, apparently, been broken off the main bone. In Fig. 17, Plate XXXVI., this is evident in the general rounding of the fragment and the consequent removal of about half of the external surface, showing the area exposed beneath covered with small incisions. Though the difference in the nature of the material renders the experiments of little value in certain respects, yet the result of treating a rounded surface made of modelling clay with the large premolars of *Thylacoleo* led to results of some interest so far as the shape of the cuts was concerned. In the case of the bone, the nature of the material introduces a factor that has doubtless much influence in deciding the ultimate form of the curve. The force used may, for example, produce first a cut of a certain curved form, and, beyond this and continuing the terminal line of the cut, it may form a fracture of varying length. This, we believe, is well shown in Fig. 7, Plate XXXVII., a narrow pointed fragment, one margin of which is convex, the other concave. The origin of the convex fracture is seen at its base, where there is unmistakable evidence of teeth having been forced into the bone from both sides. The concave side, on the contrary, bears no indication of the origin of the fracture. It may be due wholly to a fracture, or, what is more likely, the part of the broad end may be due to an incision which has been continued as a fracture to the pointed end.

Those forms selected for reference are, however, we think, free from this doubt, a strong point in their favour being the remarkable similarity in the curves of the three most striking specimens (Figs 4, 5, 6, Plate XXXVII.). Apart from those figured, it must be remembered that numbers of specimens down to some of the smallest in the collection, when carefully examined, reveal the fact that concave cuts have been made upon them. These are so constant and so frequent that we are safe in assuming that we are dealing with cuts and not with fractures. Not only are the examples numerous, but the specimens have been gathered from different places extending over a distance of one quarter of a mile along the bed of the old swamp.

It is very difficult to understand, even with the aid of such experiments as we were able to make, how certain of the cuts were produced. Other results obtained, however, were so close in their resemblance to the actual bone specimens that it seems certain that we are dealing with something more than a mere coincidence. By taking an impression of the cutting edge of both lower and upper teeth and comparing them with the curves of the specimens, they are seen to be very similar. For example, Fig. 3, Plate XXXVII., represents the impression made in clay by the hinder part of the cutting edge of the lower right premolar. If the curve of the cut edge in the model be compared with the same in Figs. 1, 2, 4, 5, Plate XXXVII., the likeness between them is striking.

Continuing the experiment, and cutting right through the clay with the tooth, the piece (Fig. 15, Plate XXXVII.) yielded by the inner side of the cutting edge is, so far as the curve is concerned, practically identical with the bone specimen (Fig. 16, Plate XXXVII.).

Other specimens again, especially those on which the cuts occur in series parallel to the length of the bone, are not sufficiently definite to give reliable results.

The concavities in Fig. 14, Plate XXXVI., and Figs. 17, 18, 19, Plate XXXVII., we quite failed to reproduce experimentally, and could only conclude that, as there is no good reason to doubt the identity of the agent of causation, and the concavities, as before mentioned, were not clear cuts, fracturing had largely influenced the contour in question. One of the concavities in Fig. 19, Plate XXXVII., especially supports this view, and might have been made by the rounded anterior end of the upper premolar, or by the formidable incisors. In connection with these, a feature in the large fragment (Fig. 1, Plate XXXVIII.) may be noticed. It is seen at one end of the specimen, and consists of a curved cut (a), through the cortex of the bone to a depth of about 3 mm., by which the cortex has been removed entirely between the cut and the fractured surface of the bone. Just close to this, and towards the more distant end of the specimen, a small concave piece (b) has also been taken out of the cortex to the same depth. The curve which forms the margin of the larger cut is in general agreement with that seen in Fig. 4, Plate XXXVII., but, so far as we can tell, it appears to have been made by the upper premolar, the anterior part of which for about 18 mm. fits remarkably well into the line of curvature. The curve must have been completed by a continued fracture. The small concavity (b) immediately behind the large curve (a) could easily be made by the anterior raised end of the cutting ridge of the tooth.

In Figs. 13, 14, Plate XXXVII., the obtuse angle, formed where the cut face (a) meets the edge of the bone (b), coincides with the angle (c) of the cutting ridge of the upper tooth

(Fig. 1A, Plate XXXIX.). Fig. 11, Plate XXXVII., represents the cut made in clay by the pressure of the upper left tooth, and it will be seen how closely the angle agrees with that of the actual bone specimen. In Fig. 14, Plate XXXVII., the edge (b) of the bone shows a fracture, but in Fig. 13, Plate XXXVII., which was apparently cut by the right upper tooth, both the cut surface (a) and the edge (b) are definite incisions.

Attention may here be drawn to the fact that, in the case of the upper premolar (Plate XXXIX., Fig. 1A), the cutting ridge is divided into two parts inclined at an open angle to one another, whilst, in the lower premolar (Plate XXXIX., Fig. 2A), the line of the ridge forms a continuous curve. Differences due to these facts are expressed in the more curved or slightly angular cuts made respectively by these teeth.

While the results of the experiments with clay have shed considerable light upon the problem we have attempted to solve, it is not held that they represent exactly what has taken place in the original operations. The difference in the nature of the material employed alone might lead to erroneous conclusions, owing to the modelling clay yielding so readily to pressure and simulating forms which perhaps would not be obtained if the natural material had been used.

Taken in conjunction, however, with the repetition of many general features and details in the specimens which we have been able to reproduce, the experiments certainly seem to bear out the assumption that *Thylacoleo* was, as far as it is possible to ascertain, the cause of the remarkable human-like sculpturing and fragmentary condition of the bones.

It should be mentioned that a careful examination of teeth-marks on bones convinced us that *Thylacoleo* had fractured some of them by a chopping action of its teeth directed on, or very close to, the same spot. A study of the surfaces of the specimens completely sliced without fracture reveals the fact that what appears at first sight in two or three cases—for example, Fig. 14, Plate XXXVII.—to be a face produced by a single continuous application of a cutting instrument, is really made up of several facets. In these instances it seems as if severance had been effected by this chopping action of the teeth on the bones, delivered at the same angle and in the same line.

It must be added that no indication of this character can be seen in most of the specimens. Such a method of working the bones would naturally not require anything like the great power necessary to force this animal's shearing teeth through bones of the thickness of those which have been operated upon.

A noticeable feature about all the cut bones, with possibly a very few exceptions, is that they appear to have been cut through by one tooth only, either the upper or the lower, as the case may be, there being no positive traces of marks of teeth on both sides of the bone or of the place where they met when severance took place. This may be associated with, and probably explained by, the fact that, with the exception of the one large piece (Plate XXXVIII., Fig. 1), all the specimens are fragments of hollow bones, and that, therefore, it is more likely that they were split by the pressure exerted in making the cuts, or maybe they were broken longitudinally by the beast after the transverse fracture had been effected.

Through the courtesy of Dr. Stirling, Director of the South Australian Museum, Adelaide, Mr. E. F. Pittman, Government Geologist of New South Wales, and Dr. Hamlyn Harris, Director of the Queensland Museum, Brisbane, we have been able to compare the tooth-marked bones found in those three States with the bones with which we have been dealing.

First, to take the bones from South Australia, which were collected from the bed of Salt Creek, Normanville, by Messrs. A. H. C. and F. R. Zietz, there is nothing of special interest to be noticed such as we find in the specimens we have described from Victoria. Nearly all the marks and cuts are what might well be expected to be produced by an animal possessing a shearing tooth like that of *Thylacoleo.* These incisions consist mostly of straight, blunt gashes crossing the bones more or less transversely; a few (Plate XXXVI., Figs. 3, 5) however, show the characteristic curve of those we have fully dealt with in describing the marked and cut bones from Pejark Marsh, but in no instance is there anything to be seen of a nature approaching the clean cuts right through the bone in specimens from Pejark, which bear so great a resemblance to the work of man. The bones are all fragmentary, being fractured both transversely and longitudinally. Some of those fractured longitudinally have undoubtedly been broken by the insertion of a pointed and not a shearing tooth, for the marks of a tooth of this character are plainly visible, which would mean, if *Thylacoleo* is the responsible agent, that his incisors were brought into play; otherwise we can only assume that some other of the contemporary carnivorous animals had also taken part in breaking and marking the bones. There is, however, as we have already stated, nothing in any of the features noted which cannot be satisfactorily explained by attributing them to some bone-eating beast or beasts such as we know existed along with the animals whose remains we have been discussing. These bones therefore do not call for further attention.

Some of the New South Wales specimens, which were found in a pleistocene deposit at Myall Creek, near Bingera, possess some points of interest. Their occurrence was described in detail by Mr. W. Anderson (1), and we quote the following from his report:—

"Occurring in the ossiferous portions of the clays were numerous small fragments of bones, generally a few inches in length, and chiefly pieces of the longer limb bones, which had been broken into fragments prior to their deposition in the clays. In almost every case the sharp fractured edges and angles of these fragments had been slightly rounded by attrition, but they were by no means so well water-worn as the pebbles which occurred along with them. The fragments of the thicker bones rarely showed an entire transverse section of the bone which had not only been fractured transversely, but also longitudinally. In the case of fragments of the thinner bones, the transverse section is generally complete, the bone not having been fractured longitudinally. The large majority of the broken fragments show unmistakably the teeth-marks of some carnivorous animal or animals. Most of these marks are, however, too fine to have been produced by the carnassial teeth of *Thylacoleo*, although there are some of them which seem large enough and coarse enough to have been so produced. The fragments of bones which show evidences of having been gnawed are chiefly pieces of the shafts of the longer limb-bones and ribs. The teeth-marks occur singly along the surface of the fragments, corresponding marks being often present on the opposite surface, indicating the action of the teeth of both jaws on the bones. Generally, however, the marks are confined to one or both ends of the fragments, which often bear evidences of having been bitten sharply off, while close to the sharply-bitten end the surface is furrowed with teeth-marks, showing that, whatever the animal was by the action of whose teeth the marks were produced, it had a similar habit to that which the dog and other carnivora possess, of holding one end of the bone on the ground between the fore-paws, while it gnawed the opposite free end. Few of the teeth-marked fragments of the bones belong to the skeletons of the larger animals whose remains occur in the deposit."

There is not much to add to what Mr. Anderson has said regarding the greater number of these specimens, and our remarks on the South Australian bones apply equally well to them. We might mention, however, that the marks stated by Mr. Anderson to be too fine to have been produced by the carnassial teeth of *Thylacoleo* are similar to those on the Pejark bones, only not so abundant, and which we have shown by experiment can be reproduced by pressure of the cutting edges of these teeth. The specimens of special interest to us from Myall Creek bear certain wedge-shaped gashes or notches which make them comparable to the Colongulac bone, and we defer a description of them until we deal with that specimen. As in the cases of the South Australian and New South Wales bones, the ones from Queensland are quite devoid of the interesting cuts exhibited by the Pejark specimens, but they differ from all the others inasmuch as, with one exception, they do not show the characteristic longitudinal fracturing. In the majority of cases the breaks occur straight across the bones, even in specimens of considerable thickness. Besides the fine markings and gash-like cuts, which are identical with those on specimens from elsewhere, there are present more or less rounded punctures or pits, and in several instances longitudinal cracks proceed from, and appear to be due to, them. Mr. De Vis (4) has figured and described some of these pits, and puts them down to the agency of *Thylacoleo*, a view with which we are in agreement. We mentioned that certain of the South

Australian specimens had been fractured lengthwise by the insertion of a pointed tooth, presumably the incisor of *Thylacoleo*, and these Queensland bones, cracked in a similar direction, strengthen the idea that much of the bone splitting has been accomplished by this means. It also gives some indication of the immense biting capabilities of the animal, which enabled it to force its incisors, modified to act as seizing and tearing teeth, into fairly solid bone far enough to cause its fracture.

It is rather puzzling to find that, while the bones from the three localities outside Victoria are marked generally with a similar type of incision, mostly in the form of a shallow gash, and distinct cuts of the Pejark type are entirely absent, the specimens from the latter place show very few shallow gashes, and cuts through the bone are comparatively plentiful. These differences in the character of the occurrences seem to point to the work having been done by teeth varying in the sharpness of their cutting edge, for it can be well understood that the shearing teeth of *Thylacoleo*, much worn down by usage, would be quite incapable of doing more than make a surface cut, or crushing the bone until it yielded to the pressure of repeated blows of the teeth, without leaving any well-defined slicing like that seen on the Pejark bones. On the other hand, it is possible, although improbable, that the Pejark specimens were softer, and did not fracture as the more brittle ones would do, but withstood the cutting action until they were completely cut through.

2.—THE BUCHAN BONE.

Another bone, found by Mr. J. A. Kershaw, of the National Museum, Melbourne, bears cuts, the origin of some of which is a matter of doubt. The specimen was found in one of the several caves in the devonian limestone of Buchan, in Eastern Gippsland, which contained the remains of extinct marsupials, including a skull of *Thylacoleo*.

That the find was a genuine one is certain, for Mr. Kershaw, who visited Buchan purposely to collect material from the caves, was one of the first three to enter this particular cave in which the bone was found, and the ground had not been previously disturbed. The cuts were not noticed until the bones collected were being cleaned in the Museum. The bone itself Plate XXXVIII., Fig 2) is apparently the cylindrical part of the shaft of a kangaroo tibia, about five inches in length, and in the same fossil condition of all the bones of extinct forms occurring in the caves.

From the substance of the piece, it seems to belong to a kangaroo as large as, or larger than, the greatest of our existing species. At the small end of the bone, commencing almost at the extremity, and extending along the prominent longitudinal ridge in the form of a double scallop (a) and (b) for about 54 mm., there is a long, almost continuous cut, as if the surface had been sliced off. The first scallop (a) is very shallow, and the further one (b), which terminates somewhat abruptly, is about 3 mm. deep, measured from the top of the ridge. The part connecting the two scallops has apparently, for about 6 mm., not been touched at all, and the ridge for that distance still remains.

The side of the bone opposite to these cuts has been gnawed for its whole length by some small rodent, such as a rat, the marks of both upper and lower incisors being perfectly distinct, but with these, which may have been added at a recent time, we do not propose to deal.

In order to compare the cuts with those which might have been made by *Thylacoleo*, a clay model approximating the bone in question was prepared, and a slice was cut from its side by the upper shearing tooth attached to a piece of the skull, taken from the cave in which the bone was found.

The resemblance of the contour of the cut so produced, when viewed from the side, to that on the bone is so remarkably close that it seems almost beyond dispute that they were both made by the same means.

The measurements, as nearly as they could be taken, agreed; and a groove corresponding to one formed by a ridge on the anterior external surface of the tooth was plainly visible in the corresponding position. The only difference noticed was in the abrupt termination of the cut made in the clay model by the posterior end of the tooth, and this might be accounted for by the depth of the cut being greater than the one on the bone, which is not quite continuous, and gives the impression that the bone was gripped by the tooth in such a way as to leave an untouched part opposite the concavity in the external surface of the tooth.

If such an explanation is deemed unsatisfactory, there can only be one alternative—that is, that it was the work of man, for there is no indication that the cut was made by any natural agency.

The Buchan bone fails to convey any idea that the cut was made to serve any useful purpose whatever, although it is conceivable it might have been incidentally caused in chopping flesh off the bone with a stone axe, a procedure most unlikely, not only on account of it being a practice not adopted by the natives, but also because the flesh on that part is a negligible quantity.

As in many caves, the bones found at Buchan appear to be odd, scattered and often fragmentary, nothing like a complete skeleton of any kind having been discovered. Also, in a number of cases, they show tooth marks of animals which have been gnawing them.

It is improbable that the herbivorous animals whose remains were found in the caves would frequent places where their natural enemies would be encountered. Moreover, the larger forms could not possibly have entered most of the caves by the present openings; hence, if they obtained admittance, or fell in, or if their bodies were washed in, it must have been through pre-existing entrances. The occurrence of the bones precludes the acceptance of the last view, although there is evidence that this particular cave was formed from what were at one time two distinct caves, as the remnants of a false roof made up of material originally deposited on the floor of an upper cave, are still to be seen. It is possible in this case that the complete remains of animals which may have fallen or been washed into the upper cave through an opening now closed were precipitated into the lower one when the false roof collapsed, thereby breaking and scattering the bones. In all probability most of the remains were originally carried into the caves by predatory beasts, and there eaten and gnawed.

The Australian aborigine as we know him, though we do not know whether he differs materially in being more superstitious than his predecessors, has usually the greatest repugnance to enter such dark and uncanny places as caves, let alone utilise them as places of residence and refuge. The so-called cave drawings that have often been described, are usually made on the walls of comparatively shallow excavations at the base of cliffs to which the term rock-shelter rather than cave is applicable. If, then, he has not changed, he has never been strictly a cave dweller, and certainly nothing has yet been discovered of sufficient importance which could in any way support a contrary opinion. There appears to be, so far as we know at present, an entire absence of his work and implements, which are so commonly found in the caves of Europe in association with the remains of extinct animals. We can only conclude then, in view of the absence of definite proof that man was at any time an occupant of the cave in which the Buchan bone was found, that the cuts were made by *Thylacoleo*.

3.—THE COLONGULAC BONE.

The bone, to which we have applied the above title, was presented to the National Museum, along with other specimens in 1909, by Mr. A. D. Hardy, F.L.S., an officer of the Forests Department. Mr. Hardy informs us that they were unearthed from a low mound near the south-eastern end of Lake Colongulac, near Camperdown, in the south-west of Victoria, by the late Mr. Wm. Adeney, who owned the Chocolyn estate about 1847-48. They passed into the hands of his nephew, Mr. Day, an officer of the Lands Department, who gave them to Mr. Hardy, and he almost immediately presented them to the Museum.

Lake Colongulac (formerly also known as Lake Timboon) is the most interesting of Victorian localities where mammalian remains have been found. The geology of the neighbourhood, including some notes on the occurrence of remains, has been briefly dealt with by Dr. T. S. Hall[1], and a more comprehensive report in "The Geology of the Camperdown and Mount Elephant Districts" was made by Messrs. H. J. Grayson and D. J. Mahony.[2] No bones have been found *in situ* as far as we are aware, those found having been picked up on the shores of the lake, but there is no doubt, like those of Pejark Marsh, that they were originally deposited in a swamp or lagoon, which was afterwards buried under the ashes ejected by the neighbouring volcanoes; the bones, in this instance being subsequently freed by the breaking up of the bed, and cast upon the shores of the lake. In consequence of the bones not having been found *in situ,* we do not know whether the animals died where the bones occurred in the original bed, and left their skeletons in a complete condition, or whether the bones were fragmentary from being washed into the lake or lagoon, or broken up in the manner of the Pejark bones.

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[1] Proc. Roy. Soc. Vic., vol. xii., pt. I, pp. 107-111, 1889.

[2] Memoirs Geol. Survey of Victoria, No. 9, 1910.

We were at first strongly of the opinion that the cuts on the Colongulac bone are of such a nature that they might with considerable certainty be attributed to man; but, after careful consideration of the bone and comparison with other specimens, referred to later, we realised the possibility of their having been made by some other agency, more particularly as some of the cut bones from Pejark Marsh, without collateral evidence to the contrary, would without doubt be put down to the work of man.

The bone (Plate XXXVIII., Figs. 3, 3A) consists of the distal portion of the 4th metatarsal of a large extinct marsupial, probably of *Palorchestes,* though it is too imperfect to identify definitely.

It seems as if an attempt had been made to sever the articular head from the shaft by means of two deep, wedge-shaped notches extending a little more than half way across the bone. The upper surface of each is at right angles to the longer axis of the bone; the lower faces slope upwards from the margin to meet the former. The greatest width of one notch is approximately 12 mm., and that of the other 10 mm. Where the two notches are confluent on the margin of the bone, the latter has been penetrated to a depth of about ·6 mm. The notch on the dorsal surface is, as nearly as can be measured, 10 mm. in depth, compared with 6 mm. in the case of the ventral one.

As the bone was found some 45 years before it came into the possession of the Museum, the doubt arises as to whether these cuts were made since its discovery.

When, however, the bones were received by us, they nearly all, including the one under discussion, had some of their matrix adhering to them, and it was only after cleaning the specimen that the true nature of the notches became evident. The whole surface shows the effect of age; the cuts, especially, instead of being smooth as new cuts would be, are more or less corroded. Again, on part of the surface of the bone there is a strongly adherent coating of calcium carbonate, which has in one place entered a notch and covered a portion of it. The notches have either been produced by man or by the teeth of some especially powerful animal. In the latter case, it is difficult to realise how the work could have been done without severing the head from the shaft. That this would have been the result of continued pressure of a wedge-shaped tooth is certain, so that the notches must be due, whatever the agent may have been, to a series of blows given in like manner that an axe is used by man.

We have previously mentioned that a study of some cuts apparently made by *Thylacoleo* leads us to believe they were produced by a similar chopping action with his premolars. The notches, however, are more particularly suggestive of human workmanship, but we are faced with the objection that we know of no instance in which Australian man has severed bones in such a manner, or, indeed, in which he has cut bones at all comparable to any of those described in this paper. The usual method seems to have been to simply break the bone transversely, or even longitudinally, by blows from a blunt implement, and subsequently, by grinding, to fashion from the piece of bone thus prepared the desired article. The consequence of this procedure is that all the bone implements we have examined where only one end has been ground, either showed the head of the bone untouched, or else the original jagged fracture without modification, in cases where the head has been removed. It seems scarcely likely, when such a simple and rapid operation accomplishes all that is required, that the prehistoric Australian native would resort to the laborious and lengthy business of chipping through a tough bone of fair substance with a stone implement in order to separate the head from the shaft, with the object of afterwards employing the latter in the manufacture of some implement or other article. We are, therefore, of the opinion that, notwithstanding the very strong resemblance to man's work exhibited in the Colongulac specimen, it is not sufficient in itself to allow us to assert that man actually made the cuts ; and the notes following on some of the tooth-marked bones from Myall Creek, N.S.W., materially support this view.

We stated previously that these particular specimens from Myall Creek bear wedge-shaped gashes which make them comparable with the Colongulac bone, and this fact considerably discounts what seemed almost a certain belief, that the latter bone received its cuts from the hand of man. Strangely enough, two out of the three bone fragments which exhibit this feature are, like the Colongulac bone, apparently parts of the 4th metatarsal of an extinct marsupial of about the size of *Palorchestes,* only in those two cases we have the proximal and not the distal half of the bones. The better of these two specimens is illustrated in Figs. 4, 4A, Plate XXXVIII. The bone is fractured longitudinally from end to end, but the side view shows the natural surface with the short transverse gashes round one end of it, resembling the impressions left by blows from a blunt tomahawk. The wedge or V-shaped cuts, two of which are seen in Fig. 4 at (a) and (b), occur beyond the transverse cuts at the extreme end of the bone. On the other side of the specimen, exactly opposite to (a), the larger of the two cuts, a third one, (c), the largest gash of all, penetrates the bone almost sufficiently deep to meet the cut (a). The end view (Plate XXXVIII., Fig. 4A) shows the characteristic wedge-form of the three cuts (a, b, c), and also the resemblance, on a reduced scale, that they bear to the Colongulac bone.

The difference in the two instances is that, in the latter, the cuts are transverse, whereas in the Myall Creek specimens the cuts are longitudinal.

There can be little doubt that the V-shaped cuts in the Myall Creek bones were made by the animal whose gnawing of the bone has left prominent evidence, in the number of short transverse gashes round the end of this and other specimens. We have, in *Thylacoleo*—for to him must be accredited all the cuts in question—an animal capable of producing by means of his shearing teeth cuts bearing a striking resemblance to the notches made by civilised man in severing certain materials with the aid of a knife or axe. There is admittedly, as regards size. a great difference between the Myall bone and the Colongulac bone, and moreover, in the latter instance we have no corroborative evidence of the work of *Thylacoleo* in the presence of markings or cuts of any kind which might safely be attributed to him. At the same time it throws much doubt upon what might otherwise unhesitatingly be accepted as the handiwork of man, more especially when we know that that work is not of a nature practised by the natives of Australia in historical times.

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EXPLANATION OF PLATES.

[All figures nearly natural size].

PLATE XXXVI.

Fig. 1.—Clay model, showing incisions made with the upper and lower premolars of *Thylacoleo.*

Fig. 2.—Section of the head of a femur, showing fine chisel-like incisions. Pejark Marsh.

Fig. 3.—Piece of a limb bone, with curved incisions. Salt Creek, Normanville, S. Australia.

Fig. 4.—Fragment of bone, with straight incisions. Salt Creek, Normanville, S. Australia.

Fig. 5.—Longitudinal sectional of a calcaneum, with curved incisions, and a serrated edge where a pointed tooth has penetrated and split the bone. Salt Creek, Normanville, S. Australia.

Fig. 6.—Shaft of a metatarsus, with curved incisions made by the lower premolar of *Thylacoleo.* The end where they occur has been fractured transversely by means of one of these incisions, as seen by the similarity of the curves. Queensland.

Fig. 7.—Small fragment fractured by a curved incision, like that of Fig. 6. An incision having a similar curve occurs close to the fracture. Pejark Marsh.

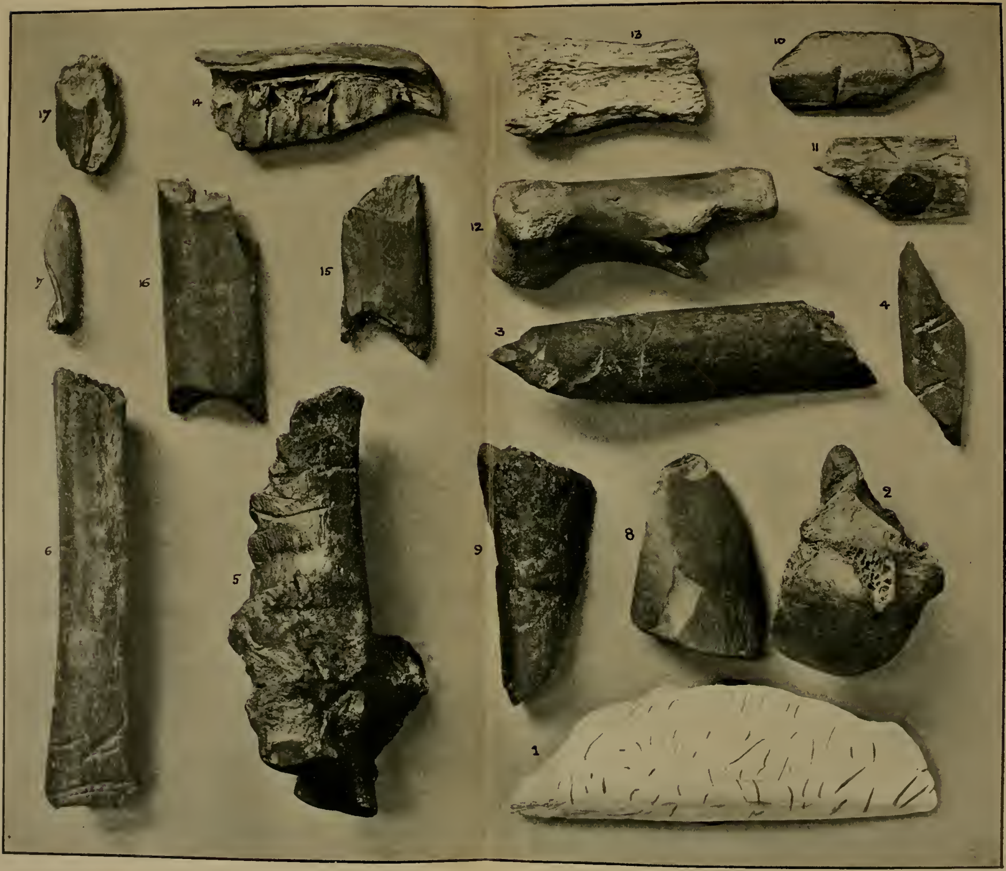
Fig. 8.—Small piece of large limb bone, showing how a tooth has penetrated the bone to a slight depth, and then pared off its surface in a broad shallow groove. Pejark Marsh.

Fig. 9.—Gash incisions. Salt Creek, S. Australia.

Figs. 10, 11.—Gash incisions. The oblique terminal fractures are evidently due to such incisions. Pejark Marsh.

Fig. 12.—Proximal phalanx of the 4th toe of a large extinct kangaroo, showing a piece broken away by the entry of a pointed tooth, leaving thereby a jagged edge. Pejark Marsh.

Fig. 13.—Longitudinal section of the underside of a phalanx similar to Fig. 12. Pejark Marsh.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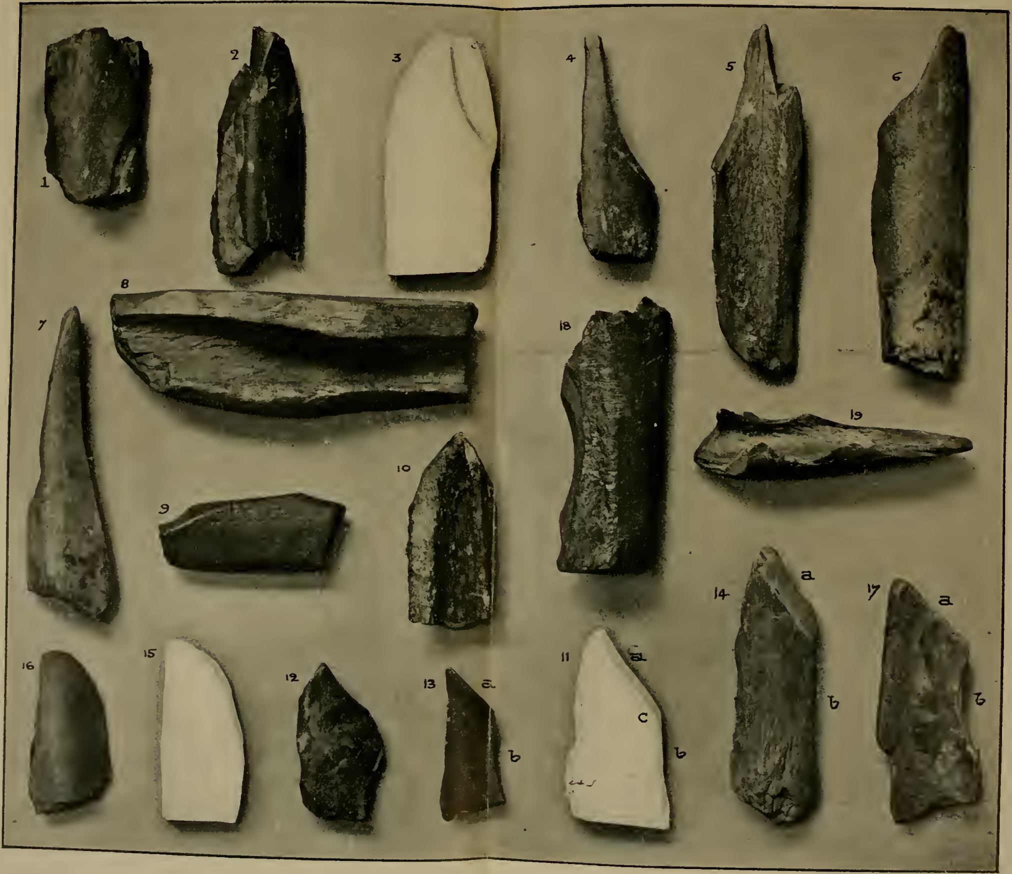
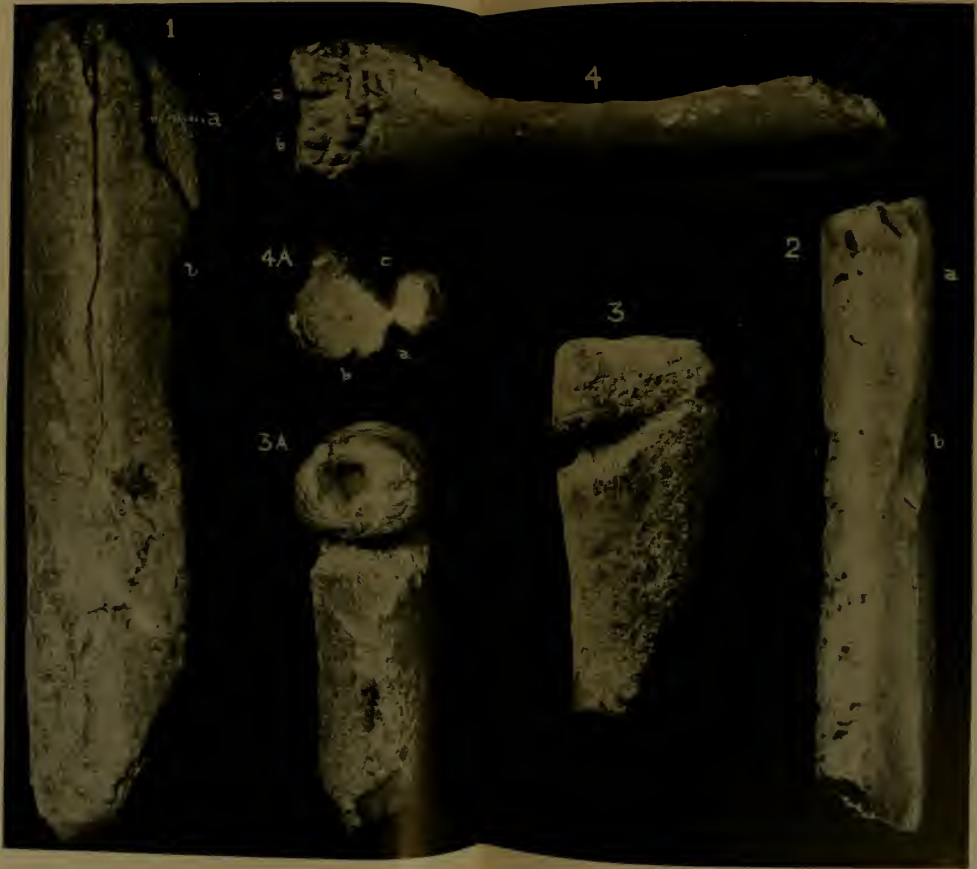
Proc. R.S. Victoria, 1911. Plate XXXVII.

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Proc. R.S. Victoria, 1911. Plate XXXIX.

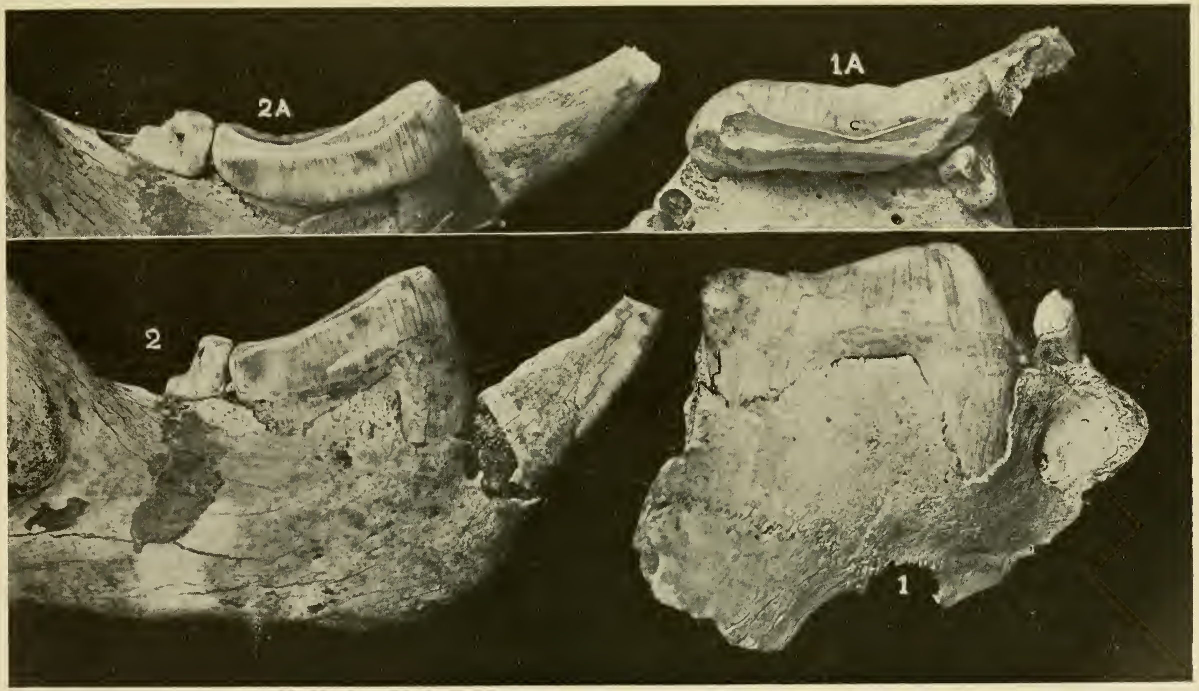

Fig. 14.—Longitudinal section of the left ramus of a kangaroo jaw, through the teeth sockets. A curved fracture has been made at a slightly oblique angle across the proximal end. Pejark Marsh.

Figs. 15, 16.—Fragments of limb bones, with forked terminations. A type of fracture which might be due to any sufficiently powerful carnivorous animal. Pejark Marsh.

Fig. 17.—Chewed bone, with about half of the surface removed. The exposed area is covered with small chisel-like incisions. Pejark Marsh.

Plate XXXVII.

Fig. 1.—Fragment of a large bone bearing an oblique curved cut across one corner. On the corner opposite, a series of scallops are imperfectly indicated. Pejark Marsh.

Fig. 2.—Fragment of a limb bone, with one of its corners sliced off by an oblique curved cut. Pejark Marsh.

Fig. 3.—Clay model, illustrating how curved cuts may be produced by the lower premolar of *Thylacoleo.*

Figs, 4, 5, 6.—Pieces of limb bones with similar oblique curved cuts, but passing through the bone at more upright angles than in the case of Fig. 2. Pejark Marsh.

Fig. 7.—Concave and convex fractures, producing a pointed fragment. The convex fracture is due to the entry of pointed teeth penetrating the bone, both from above and below; the concave fracture may have originated from an incision in the broad end of the bone. Pejark Marsh.

Figs. 8, 9.—Pieces of limb bones margined by a series of cuts (or in part by fractures produced by incisions). Pejark Marsh.

Fig. 10.—Bone pointed by two obique cuts. The left-hand edge also appears to have been sliced off. Pejark Marsh.

Fig. 11.—Clay model cut through by the upper premolar of *Thylacoleo*, illustrating the characteristic angle formed by the middle of the cutting edge of the tooth.

Figs. 12, 13, 14.—Oblique cuts producing pointed ends to bone fragments. Note the similarity of form and angle with the clay model (Fig. 11), cut with the upper premolar of *Thylacoleo*. Fig. 17 is pointed in the same manner, but the point appears to have been induced by an incision, and the bone is not cut through. Pejark Marsh.

Fig. 15.—Clay model cut through with the lower premolar of *Thylacoleo*, showing the curve left by the inner side of the tooth.

Fig. 16.—Piece of a thin bone with a similar curve to that of the model (Fig. 15), cut with the lower premolar of *Thylacoleo*. Pejark Marsh.

Figs. 17, 18, 19.—Specimens showing concavities taken out along the edges of the bones. Pejark Marsh.

PLATE XXXVIII.

Fig. 1.—Longitudinal section of a large solid limb bone, showing curved cuts at one end, which have removed the cortex to a depth of about 3 mm. Found near an aboriginal stone implement. Pejark Marsh.

Fig. 2.—"The Buchan Bone." The cylindrical part of the shaft of a kangaroo tibia, showing pieces sliced out in the form of a double scallop, resembling cuts produced artificially in clay by the upper premolar of *Thylacoleo*.

Fig. 3.—"The Colongulac Bone." Dorsal view of the distal part of the 4th metetarsal of a large extinct marsupial, probably *Palorchestes*, showing one of the large notches which occur immediately under the head of the bone.

Fig 3A.—"The Colongulac Bone," side view, showing the confluence of the two notches.

Fig. 4.—A tooth-marked bone from Myall Creek, N.S.W., bearing at its extreme end small notches, similar to those of the "Colongulac Bone."

Fig. 4A.—End of the Myall Creek bone, where two opposite notches almost meet. The resemblance to the side view (Fig. 2A) of the "Colongulac Bone" is very marked.

PLATE XXXIX.

Fig. 1.—Upper premolar of *Thylacoleo carnifex*, Owen. From a cave at Buchan, Victoria.

Fig. 1A.—Same, showing the characteristic angle in the cutting edge.

Fig. 2.—Lower premolar of *Thylacoleo carnifex*, Owen. From a cave at Buchan, Victoria.

Fig. 2A.—Same, showing the curve of the cutting edge.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. IX.—*On a Limburgite Rock occurring as a Volcanic Plug at Balwyn, near Doncaster.*

By F. CHAPMAN, A.L.S.

and

A. O. THIELE.

(With Plates XL. and XLI.)

[Read 8th June, 1911.]

General Description of the Locality and Occurrence.

The bedrock of this district is formed of more or less folded mudstones and sandy shales, belonging to the silurian (melbournian) series. The highest points in the neighbourhood are at Doncaster, Yarrabat Avenue, and Balwyn township, on the 410, 380 and 320 contour lines respectively. In common with other intermediate localities, these eminences are capped with red tertiary sands of kalimnan age (lower pliocene): remnants of the vast sheet of sand-rock which at one time formed a cover to the great Yarra or Nillumbik peneplain[1] of this part of Victoria, before it was dissected by the present river system.

The Balwyn occurrence of the basic lava herein described, and later shown to be a basic dolerite related to the limburgites, is situated in a paddock of the Whitethorn Estate (now chiefly comprised in an allotment belonging to Mr. J. R. Lewis[2]), at about 800 feet down the Whitethorn Road, north from the Belmore Road, and about 200 feet east from the road. The exposure presents the appearance of a low, but distinct mound of oval or lenticular outline, rising very slightly above the contour of the silurian rock of the immediate vicinity, and sloping down on the south-eastern side to lower ground bounded by a small creek. The mound has been rendered more conspicuous by the accumulation of excavated rubble which has been thrown out around the area worked for the stone. No actual junction with the country rock (silurian mudstone) was found, even after prolonged search; but close at hand, near the small creek before mentioned, the mudstone is indurated in a peculiar manner, and a small monadnock stands out as the result of unequal hardness and encircling denudation.

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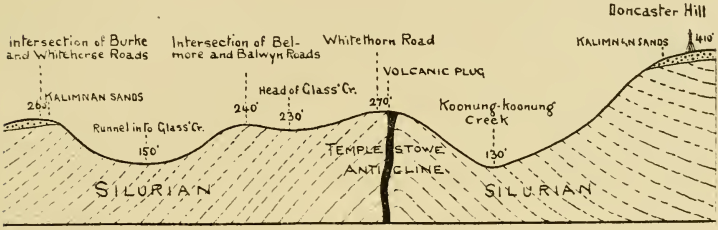
[1] For description of this peneplain see J. T. Jutson, Proc. Roy. Soc. Victoria, vol. xxiii, n.s., pt. 2, 1911, p. 447.

[2] For facilities given for access to the ground our best thanks are tendered to this gentleman.



GEOLOGICAL SECTION FROM BURKE ROAD TO DONCASTER TOWER.
LENGTH OF SECTION 4 MILES. VERTICAL SCALE EXAGGERATED 13.2 TIMES.

The height of the outcrop of the lava above sea-level is 270 feet. The exposure, which is situated on the sloping sides of the Koonung-koonung Creek basin, appears to have been discovered many years ago, and was locally used for supplying a hard stone, of which, by the way, there is a decided lack in this locality. Some of the lava was formerly employed for metalling the Doncaster Road, but was eventually given up on account of the objection of the stonebreakers to use material harder than the Collingwood bluestone, to which, together with the local indurated sandstone, they have now adverted. The conspicuous part of the mound formed by the lava and the excavated rubble is about 230 feet in length and about 100 feet broad. Altogether with the exposure of lava and volcanic soil on the south-eastern slope, this area would be increased more than four times.

The mode of occurrence of the rock at once conveys the idea that it is a volcanic plug or neck, which has broken into and through the silurian mudstone and sandstone of this district. That it is a pipe or terminal flow is fairly evident from the shape of the exposure. The rock has probably solidified at or near the surface, as there are no particularly large crystals in the magma, the phenocrysts being of very moderate size. The rock is decomposed in the superficial layer, but in the interior is dense and of a blue-black colour. There are a few vesicles in the mass, but many of the cavernous parts of the surface-material are seen to be due to the decomposition of the olivines. It was found impossible to discover a clean, exposed section of the lava, but at one spot we were able to see the jointed, rubbly rock lying on decomposed lava to some depth. Numerous joint-planes have completely broken up the rock, and the form of the fragments is platy rather than cuboidal or prismatic, as in ordinary basalt. Some of the less dense pieces, in contrast to the dark, rusty brown colour of the majority of the lava-slabs, are of an earthy yellow to sage-green colour; a difference due to the presence of a larger quantity of decomposed olivine.

Detailed Description of the Balwyn Lava.

Megascopic Characters.—Typical rock specimens are dense, and dark blue to black in the decomposed parts. The weathered surface is yellowish to dark brown, and forms a thin crust on the exposed portion. Very frequently the surface shows a pitted structure which is very conspicuous, and due to the removal of olivine phenocrysts. Fractured surfaces reveal a few glassy phenocrysts of olivine. Some of the rock fragments picked up at the excavations are rich in alteration products of the ferro-magnesian minerals, and of a dull green colour.

Microscopic Characters of the Black Lava.—Ground-mass with hyalopilitic structure; also indications of local fluxion structure, with numerous phenocrysts of olivine, large and small, and an occasional pale green augite (= diopside). The ground-mass consists of closely textured crystals of minute augites, a moderate proportion of felspar laths,[1] numerous small crystals of magnetite, and some larger platy ilmenites, together with a little interstitial brown glass. (See Plate XL., Fig. 1). Felspar microliths consisting of labradorite of the medium type, having an extinction angle of − 35 deg. Augite, chiefly occurring in the ground-mass. The crystals are of long prismatic habit, and of a deep hazel-brown colour. In the less dense samples this mineral occurs ophitically intergrown with the felspars. Average dimensions, .11 mm. × .023 mm.

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[1] In a slide of the rock analysed for the present paper, the felspars are more numerous; nevertheless the strong basic character of that particular specimen is shown by its high specific gravity (2.994).

Diopside, rare; a few phenocrysts present, of a pale green colour, and with feeble pleochroism. Several twinned crystals occur in one of the slides, which Mr. D. J. Mahony, M.Sc., was good enough to examine with us, and he confirms our determination of this mineral. The presence of diopside may account for the small percentage of Cr_2O_3 recorded in the analysis appended to this paper. Olivine, occurring, 1st—as phenocrysts, short, stout prismatic, or of tabular habit, the largest having a length of about 2 mm.; 2nd—as rounded granules, their shape being probably due to partial resorption by the magma. The olivines are colourless to pale green, somewhat corroded and often partially altered on the margins and along cleavage planes to a dull olive green or yellow substance. Several large phenocrysts of olivine exhibit a poicolitic structure, being filled with minute included crystals of ilmenite or possibly (?) picotite. (See Plate XLI., Fig. 4). The olivine also occasionally contains strings of brown glass inclusions.

Magnetite.—Abundant as small crystals disseminated through the magma, and rectangular or triangular in section; sometimes occurring in linear series. This mineral shows a tendency to form irregular zones around the olivine phenocrysts, and especially the rounded granular crystals. (See Plate XLI., Fig. 3). The magnetite is probably more or less titaniferous, as it shows some translucency, being of a brown colour in very thin sections by transmitted light.

Ilmenite.—Some medium-sized tabular crystals, showing skeleton structure around the margins, having a sub-metallic lustre by incident light. (See Plate XL., Fig. 2). Numerous minute truncated triangular crystals in this ground-mass are also probably referable to the same mineral.

Zeolites.—Analcite appears to be present as a transparent isotropic mineral filling minute, irregular cavities, and often penetrated by acicular crystals of natrolite.

Microscopic Characters of the Dark-green Lava.—The general structure of this rock is much the same as the darker, normal variety, but it has undergone much secondary change. The olivines are largely serpentinised, and the more ferriferous are changed into a substance like iddingsite, which shows marked pleochroism and prismatic cleavage cracks. Magnetite is very abundant in this rock.

The above rock is a fairly typical limburgite,[1] olivine and augite both being present, the latter forming a large proportion of the ground-mass, whilst the felspar is comparatively rare. By its mode of occurrence this rock, as Prof. Skeats has kindly pointed out, seems to be related to the monchiquites, but it is not typical, seeing that neither biotite nor hornblende occur in it. (See footnote at end of paper).

The specific gravity of this rock at 4 deg. C. is 2.994, as determined by Mr. P. W. G. Bayley, Assoc. S.A.S.M., of the Victorian Mines Department Laboratory. We are also indebted to that Department for the analysis of the Balwyn rock, prepared by Mr. Bayley. For comparative purposes the analyses of the Woodend and Bendigo examples are also appended (see last page).

Notes on some Previously Recorded Occurrences of Volcanic Plugs of a Basic Character.

Volcanic plugs and necks have been recorded from several widely separated localities in Victoria, as, for example, near Coleraine, near Castlemaine, at Anderson's Inlet, and at Woodend.

The two conical hills near Coleraine, known as Adam and Eve, which were noted by the late Mr. Dennant,[2] are in all probability volcanic plugs. Mr. Dennant states that "The rock is black and so dense that I have not been able to make any section really transparent." He also mentions the specific gravity of the rock as reaching 3. By the courtesy of Mr. R. H. Walcott, F.G.S., we have been able to examine a section of the above rock which was made by Mr. Dennant, and comprised in his collection, now at the National Museum. The slide is labelled as from Mount Adam. It closely resembles the Balwyn rock in its great density and general composition; but, nevertheless, appears rather to belong to the more basic type of the olivine basalts, since the basic oxides are not so abundant, nor the olivines so ferriferous. The Mount Adam rock may be briefly described as follows:—Ground-mass fine-grained, taxopilitic; composed of finely felted crystals of plagioclase felspars, together with minute tabular and prismatic augites and small crystals of olivine of the second generation, and fairly abundant but minute magnetite crystals. A moderate number of phenocrysts of olivine are scattered through the rock, averaging about .75 mm. in length, and with pale brown decomposition areas along the fracture planes. Also an occasional phenocryst of augite of a pale brown or wine colour.

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[1] The best known British example of limburgite is perhaps that from Whitelaw Hill, near Haddington, described by Dr. F. Hatch (Trans. Roy. Soc. Edin., vol. xxxvii., 1892, pp. 116, 117, pl. I., fig. 1). It closely resembles the Balwyn rock in its mineralogical and chemical composition, the silica being in the proportion of 40 per cent., and the magnesia 12 per cent. Its specific gravity is 3.03. A specimen from the type locality of Limburg, described by Rosenbusch, gave a specific gravity of 2.829 (See Cole, G. A. J.—"Aids in Practical Geology," 1891, p. 241).

[2] Rep. Aust. Assoc. Adv. Sci., 1893, Adelaide, p. 395. Mr. E. G. Hogg refers to the same rock as an olivine basalt (Proc. Roy. Soc. Victoria, vol xii., n.s.. 1899, p. 91).

The rock forming a volcanic neck at Mount Consultation, near Castlemaine, is described by Dr. T. S. Hall[1] as a "basalt, almost black, very fine-grained, rarely vesicular," and having "in some places a platy structure." This rock corresponds in all the above particulars with ours, the platy structure in the Balwyn rock being a very marked feature.

In South Gippsland, near Anderson's Inlet, there are numerous volcanic necks which have been described by Mr. A. E. Kitson.[2] Many of these are fragmental volcanic rocks, from which one may infer that explosive action played an important part during their extrusion. Several of the rocks mentioned in detail by Mr. Kitson resemble magma basalts, but since the actual mineralogical composition is not given, it is impossible to say whether they belong to the augites or the limburgites; the remainder are referred to olivine dolerite and basalt. The dense, hard, blue basalt of volcanic neck No. 3[1] may possibly be allied to ours. Those rocks falling into type *c* of Kitson most nearly approach that from Balwyn. They are described as "A dense or fully crystalline basalt as a rule, with or without amygdules of calcite and small patches of olivine. This occurs as small plugs and dykes."[2] These rocks are regarded by Mr. Kitson as post-jurassic in age, and almost certainly contemporaneous with the older basalt of Flinders and the Mornington Peninsula.

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[1] Proc. Roy. Soc. Victoria, vol vii., n.s. (1895), p. 81.

[2] Ibid, vol xvi, n.s., pt. 1. (1903), p. 154.

An interesting occurrence of some small plugs of dense black prismatic basalt, from south of Woodend, Macedon district, has been lately described by Professor Skeats,[3] who refers them to the limburgites. In section this rock "shows phenocrysts of fresh olivines, set in a dark, dense, fine-grained ground-mass, consisting of lath-shaped minute augites, magnetite and small felspars with a residuum of dark glass." The age of this rock Professor Skeats provisionally regards as middle cainozoic (?). In noting the structural likeness of the Woodend limburgite to that from Balwyn, it strikes one as very probable that similar volcanic effusions may yet be found traversing the older rocks in the area between the last-named locality and the district of Central Victoria, especially since the Balwyn occurrence seems to be a plug which has been uncovered by denudation from the action of the present river system;[4] and thereby indicating the possible proximity of other effusions which have not quite reached the upper limiting surface of the basal rocks, or have shrunk down again within the pipes they may have formed.

Turning to New South Wales, in the neighbourhood of Sydney, notably near Parramatta, there are numerous plugs of basic lavas ranging through the limburgites, magma basalts and augitites. These rocks are often indicated on the surface as a series of isolated lenses, and they frequently end abruptly at a few feet from the present land surface; whilst the shales through which they rise appear shattered.[5] The Sydney basic lavas are held to be of any age later than triassic. The limburgite of the Macedon district is regarded by Professor Skeats as of the last phase of effusion before the flow of the newer basalt.

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[1] Ibid, loc. cit., p. 156.

[2] Loc. cit., p. 156.

[3] Pres. Address, Sect. C, Austr. Assoc. Adv. Sci. (1909), p. 206.

[4] It is within the recollection of one of us (A.O.T.) that the early excavations were made in two or more places, and those undertaking it were guided by the stones lying on the surface.

[5] M. Morrison—"Notes on some of the Dykes and Volcanic Necks of the Sydney District, etc." Records Geol. Surv., N. S. Wales, vol. vii., pt. iv. (1904), p. 262.

The rock described by Mr. G. W. Card[1] from The Peak, Upper Burragorang, bears a marked resemblance to the Balwyn rock both in hand specimens and under the microscope, but differs essentially in having a fair amount of nepheline disseminated through the magma. A point in common between the two rocks is the occurrence of inclusions of an exogenic character, consisting of pyroxene and picotite in mutual association.

One other rock occurrence of the limburgite type from Victoria may here be mentioned, which is found in the form of dykes cutting through the older rocks, and not as volcanic plugs or necks. This is the series of basic dykes described by Mr. (afterwards Dr.) A. W. Howitt as traversing the sedimentary rocks in which the saddle reefs of Bendigo have been found.[2] According to Dr. Howitt these rocks have been injected into fissures after the formation of the quartz reefs. This particular rock is referred by Howitt to the limburgites; and he remarks that "The extraordinary freshness of some samples of this rock from Bendigo suggests that it is of comparatively late geological age." It may, therefore, belong to the same series of effusions as the Woodend and Balwyn types. The mineralogical composition of the above rock generally resembles both of the other types just mentioned, as the following notes from Dr. Howitt's description show, although it differs from both those types in having numerous crystals of amphibole in the ground-mass, whilst the felspars are entirely absent: magma of very basic character; ground-mass with pale brown to colourless glass. Microliths and skeleton crystals of amphibolite, often arranged in a stellate manner around the magnetite crystals. Felspar absent. The augite crystals follow the generation of microliths. Porphyritic crystals of augite and olivine; the latter colourless, ranging from fresh to completely altered.

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[1] Card, G. W.—"On the occurrence of Nepheline in Post-triassic Basalts of the Hawkesbury Sandstone Area." Ibid, vol. vii., pt. iii. (1903), p. 236.

[2] Howitt, A. W.—"Notes on Samples of Rocks collected in the 180 Mine at Bendigo.' Special Rep. Dept. Mines, Victoria, 1893, pp. 3, 4. Mr. R. H. Walcott, F.G.S., of the National Museum has kindly directed our attention to the above paper.

In the sequel to this paper the analyses of the Bendigo and the Woodend rocks are quoted, where it will be seen that the former is richer in lime, but otherwise they agree pretty closely, especially in the percentages of the basic elements.

Suggestions and Conclusions as to the Age and Relationships of the Volcanic Pipe at Balwyn.

The presence of basic lava in this locality leads us to look around for similar ocurrences, but without avail. Basalt occurs, it is true, to the N.W. of Heidelberg, and to the W. of Balwyn at Collingwood; but in these instances the lava is found as more or less continuous sheets filling up former river courses. They are, moreover, easily recognisable as typical lava flows of the younger, or newer volcanic, series.

The decomposed state of the lava and its comparative isolation, as well as its almost identical chemical and physical composition, as compared with well-recognised lavas of the older series of basalt flows, compels us to place this occurrence in the same category. It is here apposite to remark that Professor Skeats has referred his recorded limburgite occurrence at Woodend to the same series of the older basalts, for he gives the sequence of the alkali series of "(?) middle cainozoic" age as ranging from solvsbergite, etc. . . . to limburgite and newer basalt.[1]

As regards the age of the greater part of the flows and vents of the older basalt, the argument for their being miocene (i.e., janjukian) is strongly supported by their intercalation between beds of janjukian age on the Victorian coast,[2] and along the Moorabool Valley. The position and local occurrence of the Balwyn limburgite plug points to the probable conclusions that, assuming it was formed in miocene times (i.e., janjukian), it either cooled considerably below the original surface of the silurian bedrock, and was afterwards exposed when the Koonung-koonung Creek basin was carved out by kalimnan or post-kalimnan fluviatile denudation; or that it had already reached the original surface of the peneplain as a vent, and was subsequently planed down along with the bedrock. The former hypothesis is the more tenable, as the lava, being so tenacious, would, if extruded to the surface, have tended to weather out and stand considerably above the comparatively soft bedrock, and thus indicated its differential structure by the formation of a monadnock.

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[1] President's Address, Section C, Austr. Ass. Adv. Sci., Brisbane, 1909, p. 203.

[2] See Note on the Geology of the country about Anglesea. T. S. Hall, Proc. Roy. Soc. Victoria, vol. xxiv., n.s., pt. 1 (1899), p. 49 et seq.

That this occurrence of lava in so isolated a spot may be directly connected with crustal folding prior to the formation of the Yarra or Nillumbik peneplain, is suggested by the fact that it occurs on the Templestowe anticline of Jutson[1] (see text figure), and directed, in its major axis, with the same line of strike as that of the quartz reefs containing antimony and gold at Templestowe. The nearest occurrences of the older basalt on either side of Balwyn are at Lilydale on the east, where there is a vent represented by tuff and cinder cones; and Flemington, on the west, represented by a rather massive flow of spheroidal basalt.[2] The Lilydale volcanic series is situated close to the fault boundary of the Croydon senkungsfeld, which may be directly connected with that remarkable series of tuffs and lavas.

ANALYSES OF WOODEND, BENDIGO AND BALWYN ROCKS.

	Woodend	Bendigo	Balwyn
SiO_2 - -	43.58 -	39.32 -	45.56
Al_2O_3 - -	11.46 -	17.53 -	13.32
Fe_2O_3 - -	3.40 -	3.07 -	2.30
FeO - -	9.13 -	9.12 -	9.68
MgO - -	10.80 -	8.00 -	11.12
CaO - -	0.88 -	10.38 -	8.77
Na_2O - -	2.18 -	2.44 -	3.02
K_2O - -	2.13 -	2.04 -	1.53
H_2O+ - -	2.40 -	5.10 -	1.28

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1. Proc. Roy. Soc. Victoria, vol. xxiii., n.s., pt. 2, (1911), p. 522.

2 Note—In the discussion following the reading of the present paper, Prof. Skeats remarked on the interesting discovery of a similar monchiquite rock occurring as a dyke in the closely associated Warrandyte anticline. (See Jutson, Proc. Roy. Soc. Victoria, vol. xxiii., pt. ii., 1911, p. 528).

	Woodend.	Bendigo.	Balwyn.
H_2O – (110°C.)	0.47	2.20	0.27
CO_2	nil		nil
TiO_2	3.32	—	3.00
P_2O_5	0.95		0.71
SO_3			nil
Cl_2	trace		0.05
Cr_2O_3			0.06
MnO	—	—	0.19
NiO			0.01
CoO			trace
Li_2O			nil
	90.70	99.20	100.87
		less O	0.01
			100.86

EXPLANATION OF PLATES.

Plate XL.

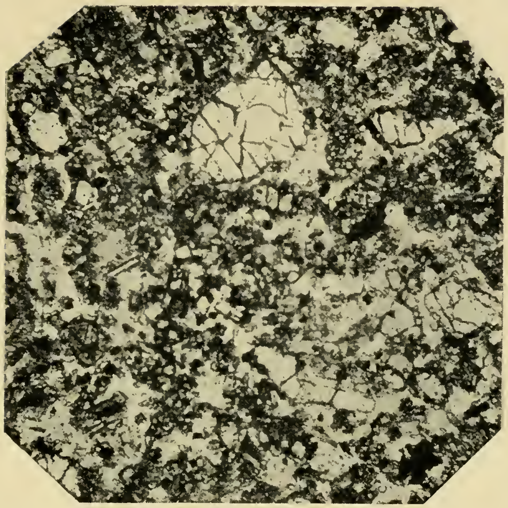
Fig. 1.—Section of limburgite-rock (monchiquite), showing general structure. × 18.

Fig. 2.—Crystal of ilmenite surrounded by olivine, felspar and augite. × 140.

Plate XLI.

Fig. 3.—Crystals of olivine, with zones of magnetite (probably titaniferous). × 140.

Fig. 4.—Intergrowth of olivine and magnetite, showing a rude centric structure (poicolitic). × 140.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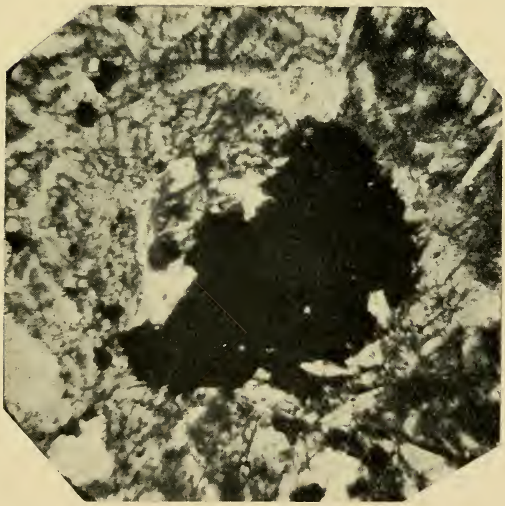
1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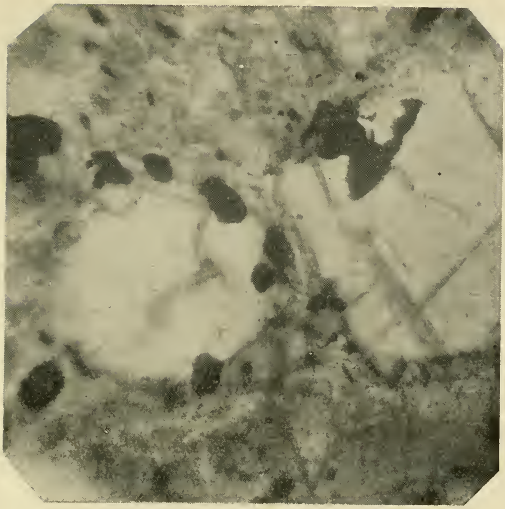

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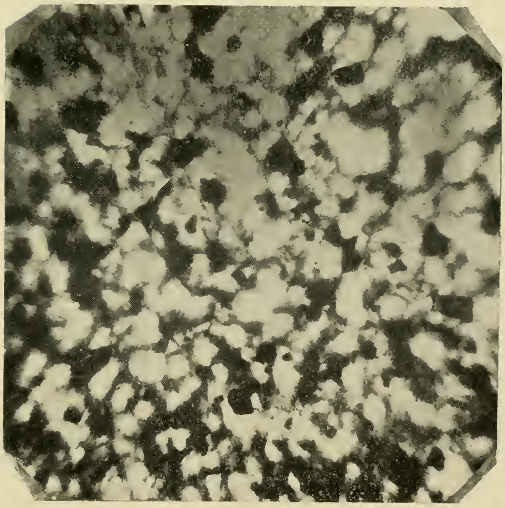

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[Proc. Roy. Soc. Victoria, **24** (N.S.), Pt. I., 1911].

Art. X.—*Descriptions de Quelques Nouveaux Espèces de Coleoptères Australiennes.*

Par A. GROUVELLE.

(Communicated by Arthur M. Lea).

[Read 13th July, 1911].

MARINE BIOLOGICAL LABORATORY
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COLYDIIDAE.

Ocholissa leai, n. sp.

Oblongo-elongatus, convexus, nitidus, flavo-albida vestitus, pilis in prothoraceque longioribus, striatis, haud densatis in striis elytrorum brevissimis, lineato-positis, in intervallis, tenuioribus, brevioribusque unilineato dispositis; antennis, capite, basi apiceque antennarum pedibusque aurantiacis, prothorace et plagua transversa in elytris nigro-piceis. Antennae breves; 3° et 4° articulis, subaequalibus, subelongatis; 1° articulo clavae quam 2° et 3° angustiore, transverso, 2° multo latiore, transverso, 3° magis quam 1° et minus quam 2° lato, transversim suboblongo. Caput transversum, convexiusculum, antice truncatum, dense punctatum, inter antennarum basim arcuatim vix impressum. Prothorax transversus, postice quam antice paulo angustus, angulis anticis rotundatis, lateribus subrectis et juxta basin sinuatus, angulis posticis obtusus, haud hebetatus, basi subarcuata, dense et capite fortius punctatus, lateribus et extremitatibus apicis basisque marginatis. Scutellum transversum. Elytra basi quam prothorax paulo latiora, humeris rotundatis, lateribus extra apicem subampliata, apice conjunctim breviter rotundata, magis duplo longiora quam simul in maxima latitudine latiora, punctato-striata; striis ad apicem impressionibus; intervallis striarum densissime tenuissimeque punctulatis, unilineato-punctatis, punctis ad apicem attenuatis; marginibus lateralibus vix plicatis. Long., 2.5 mill.

Oblong, environ trois fois plus long que large dans sa plus grande largeur, modérément convexe, brillant, couvert d'une pubescence flavo-blanchâtre, fine, couchée, assez dense sur la tête et prothorax, formée, sur les élytres, de soies très courtes inserées sur les stries et de poils encore plus courts et plus fins inserés en ligne sur les intervalles des stries, roux-orange avec le prothorax et sur les élytres avant le milieu, une large bande transversale enfumée: Antennes courtes; 3me et 4me articles des antennes subégaux, subal-longés; 1er article de la massue à peine deux fois plus large que les articles précédents, moins de deux fois plus large que long, 2me presque une fois et demie plus large que le précédent, près de deux fois plus long, 3me un peu plus étroit que le précédent, légèrement transversal, subhémisphérique. Tête subtriangulaire, environ deux fois plus large que longue, modérément convexe, tronquée en avant, densement ponctuée, impressionnée de chaque côté vers la base de l'antenne, subimpressionnée transversalement entre ces bases; épistome environ deux fois plus large à la base que long, plus densement et plus finement ponctué que le front; labre petit. Prothorax en avant nettement plus large que la tête, un peu plus étroit à la base qu'au sommet, arrondi aux angles antérieurs subparallèle sur les côtés, sinués près de la base, en angle droit émoussé aux angles postérieurs, environ une fois et un tiers aussi large que long, plus densement et plus fortement ponctué que la tête, présentant sur le disque une bande lisse, longitudinale étroite; bords latéraux et extrémités de la base et du sommet rebordées. L'écusson subrectangulaire, environ deux fois plus large que long. Elytres subtronqués à la base, arrondis aux épaules alors un peu plus larges que le prothorax dans sa plus grande largeur, à peine arrondis sur les côtés plus fortement à l'extrémité brièvement arrondis ensemble au sommet, environ deux fois plus longs que larges ensemble dans leur plus grande largeur, ponctués-striés; stries plus marquées vers le sommet; intervalles des stries très finement et très densement pointillés, chacun avec une ligne de points plus faibles que ceux des stries, atténuée vers l'extrémité. Marges latérales à peine pliées.

Tasmanie: Hobart, 1 exemplaire envoyé par Mr. A. Lea. (Collection A. Grouvelle.)

CUCUJIDAE.

Laemophlaeus molestus, n. sp.

Ovatus, modice convexus, nitidus, glaber; capite prothoraceque subrufescente-nigris; elytris viridi-nigris; articulis antennarum 1-4 labro buccaque rufo-testaceis; apice antennarum infuscato; pedibus rufo-piceis. Antennae ad apicem paulatim dilatatae; 1o articulo modice incrassato, sesquilongiore quam latiore, 2o, 3o et 4o subaequalibus, 2o subincrassato, 3o et 4o gracilibus, duplo longioribus quam latioribus, 5o, 6o, 7o subelongatis, 8o, 9o et 10o subquadratis, 11o subovato, elongato, apice acuminato. Caput subtriangulare, ad oculos duplo latius quam longius, antice sat valde trisinuatum, depressum, parce punctulatum, utrinque ad antennae basin leviter impressum; lateribus juxta basin oculorum intus sinuatis, deinde rectis et convergentibus, juxta antennarum basin rotundatis; stricte marginatis; oculis modice prominulis. Prothorax antice capite paulo latior, antice parum postice paulo magis angustus, lateribus arcuatus, juxta basin sinuatus, utrinque in longitudinem unistriatus, 1 et ½ tam in maxima latus quam elongatus; margine antico arcuato, ad extremitates subsinuato; angulis anticis rectis, hebetatis, posticis rectis; basi subtruncata, tenuissime marginata. Elytra basi prothorace paulo latiora, humeris rotundata, lateribus arcuata, apice subseparatim rotundata; circiter 1 et ½ tam elongata quam simul in maxima latitudine lata, tenuissime striatis et lineato-punctatis; stria suturali ad apicem impressa, stria humeralis tenui sed indicata, subintegra; marginibus lateralibus plicatis, valde inflexis. Long., 1.5 mill.

Ovale, modérément, convexe, brillant, glabre; tête et prothorax d'un noir très légèrement rougeâtre, élytres d'un noir un peu teinté de vert bleuâtre; articles 1 à 4 des antennes, labre et bouche roux testacés; pattes roux de poix; extrémité des antennes rembrunie. Antennes progressivement et faiblement dilatées vers l'extrémité; 1er article modérément épaissi, environ une fois et demie aussi long que large, 2me, 3me et 4me subégaux, 2me un peu moins épais que le 1er, 3me et 4me grêlés, deux fois plus longs que larges, 5me à 7me sub-

allongés, 8me à 10me subcarrés, 11me subovale, acuminé à l'extrémité, environ une fois et demie aussi long que large. Tête triangulaire, environ deux fois plus large au niveau des yeux que longue, trisinuée au bord antérieur, subdéprimée, éparsement pointillée, impressionnée de chaque côté vers la naissance de l'antenne; bords latéraux sinués en dedans à la base de l'oeil, puis droits, convergents, arrondis à la base de l'antenne finement rebordés; yeux médiocrement saillants, laissant libre entre eux et la base de l'antenne une distance égale environ à leur diamètre longitudinal. Prothorax subcordiforme, médiocrement rétréci au sommet, un peu plus à la base, environ une fois et demie aussi large dans sa plus grande largeur que long; éparsement pointillé, longitudinalement strié de chaque côté; bord-antérieur arqué faiblement sinué aux extrémités; angles antérieurs droits émoussés; étroitement impressionnés; côtés très finement rebordés, arqués, sinués près de la base, dèterminant la plus grande largeur du prothorax vers les 3/5 de la longueur à partir de la base; angles postérieurs droits, non émoussés, base subtronqué, très finement rebordée. Ecusson triangulaire, transversal, presqu'égal au tiers de la largeur du prothorax à la base. Elytres un peu plus larges que le prothorax à la base, arrondis aux épaules, arqués sur les côtés assez élargis, arrondis presque séparément au sommet, environ une fois et demie aussi longs que larges ensemble dans leur plus grande largeur, à peine visiblement striés et ponctués en lignes; stries suturales marquées vers le sommet; stries humérales, indiquées, presqu'entières; marges latérales fortement inclinées, pliées. Cavités des hanches antérieurs étroitement formées, celles-ci écartées, suture latérale partant des hanches antérieures marquées, n'atteignant pas le bord latéral. Hanches intermédiaires tres écartées. Mesosternum et metasternum à peine pointillés, le 1er plan, le 2me longitudinalement strié dans la moitié apicale. Premier segment de l'abdomen moins de deux fois plus court que le metasternum, très largement subtronqué entre les hanches postérieures.

Australie; Queensland, Cairns, 1 exemplaire envoyé par Mr. A. Lea. (Collection A. Grouvelle.)

Laemophlaeus subpallidus, n. sp.

Elongatus, subparallelus, subdepressus, nitidulus, tenue flavo-pubescens, testaceus; antennis, capite prothoraceque rufo-testaceis. Antennae subbreves, clava triarticulata; 1o articulo incrassato, parum elongato, 2o subincrassato, sub elongato, 3o—8o gracilibus, plus minusve subquadratis vel subtransversis; clava elongata, parum incrassata articulis subaequalibus, sat elongatis. Caput subtriangulare, transversum, antice truncatum, depressum, parce punctulatum, utrinque ad antennae basin impressum; lateribus ad oculis basin sinuatis, deinde rectis, convergentibus, ad antennae insertionem sinuatis, tenuissime marginatis; labro magno; oculis parum prominulis. Prothorax antice quam capite tam latus, vix angustus, basin versus angustior, lateribus bisinuatus, tam elongatus quam in maxima latitudine latus, utrinque in longitudinem unistriatus; disco medio, in longitudinem excepto, subdense punctulato; angulis posticis rectis, haud hebetatis. Scutellum subpentagonale, transversissimum. Elytra basi truncata, humeris late rotundata, tenuiter denticulata, prothorace in maxima latitudine paulo latiora, lateribus parum arcuata, modicissime ampliata, apice conjunctim rotundata, 2 et ½ tam elongata, quam simul in maxima latitudine lata; singulo elytro tenuiter striato, intervallis striarum unilineato punctulatis; marginibus lateralibus plicatis. Long., 1.5 mill.

Subparallèle, plus de trois fois et demie plus long que large dans sa plus grande largeur, subdéprimé, un peu brillant, très finement et peu densement pubescent, testacé, antennes, tête et prothorax roux testacés. Antennes assez courtes, à massue peu marquée de trois articles lâches; 1er article épais, un peu allongé, 2me un peu moins épais, suballongé, 3me à 8me grêlés, plus ou moins subcarrés ou subtransversaux; massue allongée, formée de trois articles subégaux, environ une fois et un tiers aussi longs que larges. Tête subtriangulaire, presque deux fois plus large au niveau des yeux que longue, tronquée en avant, presque déprimée, éparsement pointillée, impressionneé de chaque côté vers la naissance de l'antenne, substriée-impressionnée entre ces bases; bords latéraux sinués à la base des yeux, puis droits, convergents, sinués à la base de l'antenne, très finement rebordés; épistome plus de trois fois

plus large à la base que long; labre environ deux fois plus large à la base que long, tronqué au bord antérieur; yeux médiocrement saillants, séparés de l'insertion de l'antenne par une distance à peu près égale au diamètre longitudinale de l'oeil. Prothorax en avant à peu près de la largeur de la tête, à peine rétréci au sommet, plus fortement à la base, bisinué sur les côtés, présentant sa plus grande largeur un peu avant le sommet, environ aussi long que large dans sa plus grande largeur, longitudinalement strié de chaque côté, assez densement pointillé sur les côtés du disque, présentant sur le milieu une étroite bande lisse, séparant deux vagues impressions longitudinales; espace entre les côtés et les striés latérales densement ponctué; côtés très finement rebordés; angles postérieurs droits, non saillants; base arquée, sinuée aux extrémités. Ecusson subpentagonal, plus de deux fois plus large que long, égal dans sa plus grande largeur environ au tiers de la largeur du prothorax à la base. Elytres tronqués à la base, assez largement arrondis aux épaules, subdentés, alors un peu plus larges que le prothorax dans sa plus grande largeur, très faiblement arqués sur les côtés sauf au sommet, arrondis ensemble au sommet, environ deux fois et demie aussi longs que larges ensemble dans leur plus grande largeur, chacun avec trois fines stries sur le disque, séparées par une ligne pointillée; marges latérales pliées, fortement infléchies. Cavités des hanches antérieures ouvertes, celles-ci écartées. Hanches intermédiaires un peu plus écartées. Mesosternum infléchi en avant. Metasternum sans strie longitudinale, subtronqué entre les hanches postérieures; celles-ci écartées comme les hanches intermédiaires.

Australie: Nouvelle Galles du Sud, Forest Reefs, 3 exemplaires envoyés par Mr. A. Lea.

Cette description est faite sur un exemplaire male; chez la femelle les antennes sont plus courtes, la tête est moins large, et le prothorax relativement moins developpé en avant.

Voisin de *L. pallidus*, Lea, différent par sa forme plus large, son prothorax convexe, et ses antennes plus longues (ex auct.).

Laemophlaeus mendax, n. sp.

Oblongo-elongatissimus, subdepressus, nitidulus, tenue pubescens, fusco-testaceus; capite prothoraceque subrufescen-

tibus; antennis pedibusque testaceis. Antennae breves, clavae triarticulatae; articulis 1.2 sat valde incrassatis, subquadratis, 3º-8º gracilibus, 3º subquadrato, aliis plus minusve transversis; 1º et 2º articulo clavae transversis, 3 subhemispherico. Caput triangulare, fere tam elongatum quam latum, antice truncatum, sat convexum, inter antennarum bases et in longitudinem frontis subvalde striatum, subdense et subvalde punctatum; lateribus juxta oculos sinuatis, antice rectis et convergentibus, ad basin antennarum sinuatis, strictissime elevato-marginatis; oculis prominulis. Prothorax suboblongus, antice quam postice vix angustus, lateribus subparallelus, angulis oblique subarcuato-truncatus, subelongatus, utrinque in longitudinem unistriatus; disco depresso in longitudinem leviter biimpresso et valde punctatus, spatio inter impressiones subelevato laevi, lateribus praecipue ad basin subtilissime crenulatis. Scutellum transversum, subpentagonale. Elytra basi sinuata, humeris breviter rotundata, subdentata, prothorace parum latiora, lateribus modice arcuata, apice conjunctim rotundata, fere 2 et 1/3 tam elongata quam simul in maxima latitudine lata, in disco subvalde praecipue ad apicem tristriata; intervallis striarum ad basin unilineato-punctata; marginibus lateralibus plicatis. Long., 1.6 mill.

Oblong, presque quatre fois plus long que large dans sa plus grande largeur, subdéprimé, un peu brillant, très finement et peu densement pubescent, testacé, légèrement enfumé; tête et prothorax un peu teintés rougeâtre; antennes et pattes testacées. Antennes courtes, à massue de trois articles; 1er et 2me article de l'antenne, surtout le 1er, épaissis, tous deux subcarrés, articles 3 à 8 grêlés, les premiers subcarrés, les suivants devenant progressivement plus transversaux; massue légèrement dissymétrique, les deux premiers articles transversaux, le 3me subhémisphérique. Tête triangulaire, presqu' aussi longue que large au niveau des yeux, tronquée au bord antérieur, assez convexe, fortement et densement ponctuée, fortement striée entre les bases des antennes, longitudinalement et assez fortement striée sur le front; épistome transversal, finement ponctué; labre visible; bords latéraux échancrés par les yeux, puis droits, convergents, sinués à la naissance de l'antenne, finement rebordés; yeux saillants, séparés de la base de l'antenne par une distance subégale à leur

diamètre longitudinal. Prothorax suboblong, un peu plus large dans sa plus grande largeur que la tête, à peine rétréci en avant, largement arrondi aux angles, presqu'obliquement tronqué, faiblement arrondi sur les côtés, presqu' parallèle, un peu plus long que large, longitudinalement strié de chaque côté; disque déprimé densement et fortement ponctué, marqué de deux impressions longitudinales, superficielles, mieux marquées aux extrémités séparées par un espace longitudinal, étroit, espaces entre les côtés et les stries longitudinales plus finement et plus éparsement ponctués; côtés finement rebordés, à peine visiblement crénelés dans la partie basilaire; base impressionnée de chaque côté vers les extrémités, celles-ci très finement denticulées. Ecusson subpentagonal, transversal, égale environ au quart de la longeur de la base du prothorax. Elytres subsinués à la base, arrondis aux épaules, subdentés, alors un peu plus larges que le prothorax dans sa plus grande largeur, modérément arrondis sur les côtés, plus fortement vers l'extrémité, presentant leur plus grande largeur vers le milieu de la longueur, ensemble au sommet, environ deux fois et un tiers aussi longs que larges ensemble dans leur plus grande largeur, chacun avec trois stries bien marginées, surtout vers le sommet; intervalles des stries ponctués en ligne dans la region basilaire; marges latérales pliées, fortement infléchies. Cavités des hanches antérieures ouvertes, celles-ci un peu écartées. Hanches intermédiaires assez écartées. Mesosternum plan. Metasternum sillonné vers le sommet. Premier segment de l'abdomen plus de deux fois plus court que le metasternum, saillant en angle arrondi entre les hanches postérieur; celles-ci moins écartées que les hanches intermédiares.

Australie; Nouvelle Galles du Sud, Jenolan, 1 exemplaire envoyé par Mr. A. Lea. (Collection A. Grouvelle.)

Laemophlaeus inauditus, n. sp.

Oblongo-elongatissimus, subdepressus, nitidulus, tenue pubescens, ruffo-testaceus, elytris parum infuscatis. Antennae breves, clavae triarticulatae; articlis 1.2 sat valde incrassatis, 1o parum elongato, 2o subquadrato, 3o-8o gracilibus, submoniliformibus; clavae 1o et 2o articulo transversis, 3o subhemi-

sphérico. Caput triangulare, tam elongatum quam latum, antice truncatum, modice convexiusculum, inter antennarum bases sat valde subarcuatim striatim; fronte dense punctulata, in longitudinem breviter striata, lateribus rectis, convergentibus, strictissime elevato-marginatis; oculis leviter prominulis. Prothorax suboblongus antice quam postice paulo latior, subelongatus, subdense punctulatus, utrinque in longitudinem unistriatus, in disco depressus, antice posticeque transversim subimpressus; angulis anticis posticisque sat late rotundatis. Scutellum transversum, subpentagonale. Elytra basi truncata, humeris rotundata, prothorace vix latiora, lateribus parum arcuata, apice conjunctim late rotundata, circiter 2 et ½ tam elongata quam in maxima latitudine lata, in disco tris-triata; striis ad apicem impressionibus, intervallis striarum unilineato-punctatis; marginibus lateralibus plicatis, valde inflexis. Long., 1.5-1.8 mill.

Oblong, environ quatre fois plus long que large dans sa plus grande largeur, subdéprimé, un peu brillant, très finement et peu densement pubescent, roux testacé avec les élytres légèrement rembrunis. Antennes courtes, à massue de trois articles; 1er et 2me articles également épais, 3me à 8me grêlés, 9me à 11me formant une massue lâche, un peu plus épaisse que les 2 premiers articles; 1er article un peu allongé, 2me subcarré, 3me à 8me plus ou moins subtransversaux, articles 1 et 2 de la massue transversaux, 3me subhémisphérique. Tête triangulaire, sensiblement aussi longue que large avec les yeux, subtronquée en avant, subconvexe, densement pointillée et longitudinalement striolée sur le front, assez fortement striée entre les naissances des antennes, épistome presque lisse, bords latéraux de la tête droit, non échancrés par les yeux, très finement relevés rebordés; yeux à peine saillants, occupant les deux tiers de la distance de la base de la tête à la naissance de l'antenne. Prothorax suboblong, un peu rétréci à la base, un peu plus large dans sa plus grande largeur que la tête, un peu allongé, largement arrondi aux angles antérieurs et postérieurs, longitudinalement strié de chaque côté, assez densement ponctué, déprimé sur le disque, presque creusé d'une large impression longitudinale, plus accentuée aux extrémités; marge basilaire impressionnés de chaque côté vers les extrémités. Ecusson transversal, subpenta-

gonal. Elytres de la largeur du prothorax à la base, arrondis aux épaules, faiblement arqués aur les côtés, plus fortement vers l'extrémité, très faiblement élargis, largement arrondis ensemble au sommet, environ deux fois et demie aussi longs que larges ensemble dans leur grande largeur, chacun avec trois stries plus accentuées à l'extrémité, sépareés par une ligne de points; pli humeral marqué; marge latérale fortement inclinée. Cavité des hanches antérieurs ouvertes, celles-ci très rapprochées. Hanches intermédiaires assez éloignées. Mesosternum plan. Metasternum longitudinalement sillonné sauf à la base. Premier segment de l'abdomen plus de trois fois plus court que le metasternum, saillant en angle aigu émoussé entre les hanches postérieurs. Dernier segment de l'abdomen du male creusé d'une forte impression déterminant de chaque côté un lobe arrondi, convexe.

Tasmanie: Frankford, 4 exemplaires envoyés par Mr. A. Lea. (Collection A. Grouvelle.)

Laemophlaeus frater, n. sp.

Elongatus, subparallelus, subdepressus, tenue flavo pubescens, testaceus, antennis, capite prothoraceque rufo-testaceis. Antennae elongatae, clavae triarticulatae; 1o articulo modice incrassato, apud marem sesquilongiore quam latiore, 2o subincrassato, praecedente paulo breviore, 3o, 4o, 6o et 8o gracilioribus, subaequalibus, quam 2 paulo latiore, 5o et 7o subaequalibus quam aliis oblongioribus; clava elongata, praecedentibus paulo latioribus, articulis subaequalibus, modice elongatis. Caput subtriangulare, transversum, antice truncatum, convexiusculum, parce punctulatum, utrinque ad antennae basin impressum; lateribus ad oculi basin sinuatis, deinde rectis, convergentibus, ad antennae insertionem sinuatis, tenuissime marginatis; labro magno; oculis parum prominulis. Prothorax basin versus angustus, lateribus bisinuatus, tenuissime marginatus, 1 et ¼ tam in maxima latitudine latus quam elongatus, utrinque in longitudinem striatus; disco bi-subfoveolato, parce punctulato, basi arcuata, ad extremitates subsinuata; angulis posticis rectis, haud hebetatis. Scutellum subpentagonale, transversissimum. Elytra basi truncata, prothorace latiora, humeris rotundata, lateribus parum arcuata, modicissime ampliata, apice separatim latissime rotundata, paulo magis duplo longioribus quam simul in maxima latitudine latiora; singulo elytro tenuiter tristriato, intervallis striarum unilineato-punctulatis; marginibus lateralibus carinatis. Long., 1.4 mill.

Subparallèle, plus de 3 fois ½ aussi long que large dans sa plus grande largeur, subdéprimé, très finement et peu densement pubescent, testacé; antennes, tête et prothorax testacés-rougeâtres. Antennes allongées à massue peu marquée de trois articles lâches; 1er article épaissi, environ une fois et demie aussi long que large chez le male, 2me un peu épaissi, un peu plus courts que le précédent les suivants plus grêlés, le 3me, le 4me, le 6me et le 8me subégaux, un peu plus courts que le 2me, le 5me et le 7me subégaux, un peu plus longs que les précédents; massue allongée, formée de trois articles subégaux, nettement plus longs que larges. Tête triangulaire, presqu'aussi longue que large au niveau des yeux, tronquée en avant, faiblement convexe, éparsement pointillée, à peine visiblement striée entre les bases des antennes; bords latéraux sinués à la base des yeux, puis droits, convergents, sinués à la base des antennes, très finement rebordés; épistome plus de deux fois plus large à la base que long, labre environ deux fois plus large à la base que long, subsinué au bord antérieur; yeux médiocrement saillants, séparés de l'insertion de l'antenne par une distance à peu près égale à la moitié de leur diamètre longitudinal. Prothorax en avant à peu près de la largeur de la tête, rétréci à la base, bisinué sur les côtés, présentant sa plus grande largeur au delà du deuxième tiers de la longueur à partir de la base, environ une fois et un quart aussi large dans sa plus grande largeur que long, longitudinalement strié de chaque côté, éparsement pointillé sur le disque et biimpressionné; côtés, très finement rebordés; angles postérieurs droits, non émoussés; base arquée, sinuée aux extrémités. Ecusson subpentagonal, plus de deux fois plus large que long, égal au tiers de la largeur du prothorax à la base. Elytres subsinués à la base, un peu plus larges que le prothorax, arrondis aux épaules, très faiblement arqués sur les côtés, sauf au sommet, à peine élargis, très largement arrondis séparément au sommet, un peu plus de deux fois plus longs que larges ensemble dans leur plus grande largeur, chacun avec trois fines stries sur le disque; intervalles des stries avec un ligne de petits points; marges latérales carénées, fortement infléchies. Cavités des hanches antérieures ouvertes; celles-ci écartées. Hanches intermédiaires un peu plus écartées. Mesosternum infléchi en avant. Metasternum sans strie longitudinale, subtronqué entre les hanches postérieures, celles-ci écartées comme les hanches intermédiaires.

Australie: Nouvelle Galles du Sud, Richmond R., 4 exemplaires envoyés par Mr. A. Lea. (Collection A. Grouvelle.)

Cette description est faite sur un exemplaire male; la femelle a les antennes plus courtes, la tête moins large, le prothorax également moins large en avant et par suite paraissant moins rétréci à la base.

Silvanus crenicollis, n. sp.

Ovatus, convexus, nitidulus, pube flava, brevissima, in elytris lineato-disposita vestitus, brunneo-testaceus; antennis capite prothoraceque subrufescentibus. Antennae breves, subgraciles; clava triarticulata; 1o articulo incrassato parum elongato, 2o subquadrato, fere tam incrassato, 3o sesquilongiore quam latiore, vix incrassato, 4o subquadratis, 5o-8o plus minusve modice transversis, 2o articulo clavae quam 1o et 3o paulo latiore, 1o et 2o transversis, 3o subovato, subtransverso. Caput transversum, fronte subdepressum, antice inflexum, crebre punctatum, lateribus strictissime elevato-marginatum; oculis prominulis, granis haud minimis; temporibus nullis. Prothorax antice quam capite haud latior, antice parum, postice paulo magis angustus, lateribus modice arcuatus, 1 et 1/5 in maxima latitudine tam latus quam elongatus, crebre et fortius capite punctatus; margine antico arcuato, angulis anticis obtusis, vix dentatis; lateribus inter angulos anticos et posticos sex denticulos latos et vix productis armatis; angulis posticis obtusis, vix dentatis; basi arcuata, utrinque subsinuata. Elytra basi prothorace haud latiora, humeris rotundata, lateribus arcuata, modice ampliata, apice conjunctim rotundata, fere duplo longiora quam simul in maxima latitudine latiora, striato-punctata; striis apicem versus attenuatis, ad latera magis impressis; intervallis striarum quam punctis haud latioribus; stria marginalis impressis, intervallo marginalis unilineato-punctata. Long., 1.5 mill.

Ovale, environ deux fois et demie plus long que large dans sa plus grande largeur, convexe, un peu brillant, couvert d'une pubescence, flave un peu dorée, modérément fine, très courte, éparse sur la tête et le prothorax, inclinée et disposée en ligne sur les stries des élytres et leurs intervalles, d'un brun testacé avec les antennes, la tête et le prothorax légèrement teintés de rougeâtre. Antennes grêlés, terminées par une massue de trois articles séparés; 1er article épais, un peu allongé, 2me presqu'aussi épais que le 1er, suballongé, 3me subégal au précédent, mais sensiblement moins épaissi, 4me à 8me articles subcarrés ou subtransversaux; 2me article de la massue plus large que le 1er et le 2me, 1er et 2me transversaux, 3me ovale, environ aussi long que large. Tête triangulaire, presque deux fois aussi large que longue, subdéprimée sur le front, infléchie en avant, couverte d'une ponctuation très serrée, plus ou moins confluente, subrugueuse, presqu'effacée sur l'épistome, très finement et assez fortement rebordée, relevée sur les côtés; labre très petit; saillie des yeux assez forte, mais inférieure à leur diamètre longitudinal, granulations moyennes; tempes nulles. Prothorax aussi large en avant que la tête au niveau des yeux, un peu moins large à la base qu'au sommet, faiblement arrondi sur les côtés, environ une fois et un cinquième aussi large dans sa plus grande largeur que long, couvert d'une ponctuation très serrée, un peu plus forte que celle de la tête, plus ou moins confluente; bord antérieur arqué, subsinué aux extrémités; angles antérieurs obtus, armis d'une dent assez large et courte; côtés armés en comprenant les denticules des angles antérieurs et postérieurs, de six denticules larges, plus courts que larges à la base, irregulièrement espacés; angles postérieurs obtus, dentis comme les angles antérieurs; base arquée, subsinuée de chaque côté. Ecusson très transversal, subrectangulaire, presqu'égal au tiers de la largeur du prothorax à la base. Elytres légèrement convexes sur le disque, subsinués à la base, assez brièvement arrondis aux épaules, très modérément arrondis sur les côtés dans la partie basilaire, présentant leur plus grande largeur au delà du 2me tiers de la longeur à partir de la base, arrondis ensemble au sommet, presque deux fois aussi longs que larges dans leur plus grande largeur, ponctués-striés; stries attenuées vers le sommet; intervalles discoidaux des stries sensiblement aussi larges que les points, plans; strie marginale enfoncée, plus fortement ponctuée, intervalle marginal assez large, avec une ligne de points, 1er intervalle latéral convexe, plus large que les points de la strie marginale; stries suturales entières. Prosternum subrugueux sur le disque, éparsement ponctué sur les côtés en avant du sillon latéral des hanches antérieurs; celles-ci médiocrement marqués n'atteignant pas le bord latéral; bord antérieur bordé par un courselet: metasternum longitudinalement sillonné, à peine à la base plus fortement au sommet, presque lisse sur le disque, ponctué vers les angles postérieurs; 1er segment de l'abdomen beaucoup plus court que le metasternum, saillant en angle obtus entre les hanches postérieures, peu densement pointillé. Hanches intermédiaires écartées.

Australie: Cairns, 2 exemplaires envoyés par Mr. A. Lea. (Collection A. Grouvelle.)

Silvanus peculiaris, n. sp.

Elongatissimus, subparallelus, modice convexus, nitidulus, pube flava brevissima, sparsa in capite prothoraceque, lineato-posita in elytris, vestitus, nigro-brunneus, antennis pedibusque rufo piceis. Antennae breves, subincrassatae, 1o articulo incrassato, subquadrato, 2o paulo minus incrassato, subtransverso, 3o paulo incrassato, subelongato, 4o-8o paulatim transversioribus; clava triarticulata, articulis densatis, 1o et 2o transversis, 3o praecedentibus angustiore, transversim suboblongo, apice acuminato. Caput subparallelum, elongatum, antice rotundatum, depressum, dense subrugoso-punctatum, lateribus juxta oculos strictissime elevato-marginatis, oculis parum prominulis; temporibus minimis, angulosis. Prothorax antice quam caput paulo latior, basin versus vix angustus, 1 et ¼ tam elongatus quam latus, disco depresso, dense subrugoseque punctatus; margine antico arcuato, utrinque sinuato; angulis anticis denticulo hebetato, extus producto, armatis; lateribus inter angulos anticos et posticos quatre dentius latis, haud elongatis, hebetatis armatis; angulis posticis dentatis; basi valde arcuata, extus sinuata. Elytra ad basin prothorace paulo latiora, oblongo-elongata, apice subseparatim rotundata, magis ter longiora quam simul in maxima latitudine latiora, tenuiter punctato-lineata, intervallis alternis praecipue ad basin, ad latera et ad apicem subelevatis; intervallis humeralibus plicatis, subcarinatis; marginibus lateralibus inflexis, lateribus tenuiter marginatis, vix perspicue crenulatis. Caput subtus inter oculos angustior. Long., 3.5 mill.

En ovale très allongé, subparallèle, environ plus de cinq fois plus long que large dans sa plus grande largeur, modérément convexe, un peu brillant, couvert d'une pubescence flave très courte, rare sur la tête et le prothorax, inclinée et disposée en lignes sur les stries des élytres et leurs intervalles, d'un brun foncé avec les antennes et les pattes un peu rougeâtres. Antennes inserées notablement en avant des yeux, 1er article épais, subcarré, 2me un peu moins épais, subtransverse, 3me faiblement épaissi, suballongé, 4me à 8me d'abord subcarrés puis devenant progressivement transversaux; massue formée de trois articles brusquement plus larges que les précédents; 1er article transversal, 2me un peu plus large que le 1er, à peine plus court, 3me plus étroit que les deux premiers, à peine aussi long que large, suboblong, acuminé à l'extrémité. Tête subparallèle, attenuée, arrondi en avant, environ une fois et un quart aussi longue que large, déprimée sur le front, légèrement infléchie en avant, couverte d'une ponctuation serrée, subrugueux, s'atteignant notablement sur l'épistome, très étroitement et faiblement relevée contre les yeux; yeux peu saillants, granulations fines; tempes petites anguleuses. Prothorax un peu plus large que la tête en avant, à peine rétréci à la base, à peine arqué sur les côtés, environ une fois et un quart aussi long que large, largement déprimé sur le disque avec un vestige de caréné longitudinal, couvert d'une ponctuation plus forte que celle de la tête, très serrée, subrugueuse; bord antérieur fortement arqué, sinué aux extrémités; angles antérieurs, armés d'une dente un peu émoussée, saillants latéralement; côtés armés entre les dents des angles antérieurs et postérieurs de 4 dents larges, peu saillants émoussées; dents des angles postérieurs triangulaires, non émoussées; base très fortement arquée dans le milieu, sinuée aux extrémités. Ecusson très transversal, subrectangulaire, aussi, large environ que le cinquième de la largeur du prothorax à la base. Elytres sinués à la base, arrondis aux épaules, en ovale très-allongés, un peu plus larges que le prothorax, presqu'arrondis, séparément à l'extrémité, environ trois fois et un tiers aussi longs que larges ensemble dans leur plus grande largeur, finement ponctués en lignes, substriés; intervalles alternés des lignes ponctuées subélevés surtout à la base; sur les côtés et vers le sommet; intervalle humeral plié, subcaréné; marges latérales fortement déclivés, finement rebordées, à peine visiblement crénelées. Yeux n'échancrant pas en dessous les marges latérales de la tête. Prosternum couvert sur les côtés de points serrés, superficiels, ocellés; bord antérieur bordé par un courselet; metasternum assez densement ponctué longitudinalement sillonné sauf à la base; 1er segment de l'abdomen beaucoup plus court que le metasternum, saillant en angle aigu entre les hanches postérieures, presque lisse au milieu, ponctué sur les côtés, présentant des stries femorales courtes, subparallèles. Hanches intermédiaires séparées.

Australie: Victoria, Birchip, 1 exemplaire envoyé par Mr. A. Lea. (Collection A. Grouvelle.)

EROTYLIDAE.

XENOSCELINI.

Xenoscelinus tasmanicus, n. sp.

Oblongus modice convexus, pube flavo-grisea subdense vestitus; castaneo-testaceus; capite prothoraceque piceis. Antennae breves, clavae biarticulatae; 1o articulo transverso; ultimo glandiforme. Caput convexiusculum, dense punctulatum; granis oculorum mediocribus. Prothorax magis duplo latior quam longior, angulis anticis subrotundatus, lateribus bisinuatus, angulis posticis rectus, haud hebetatus; lateribus tenuiter marginatis; basi subtruncata et ad apicem subsinuata. Elytra prothorace ad basin paulo latiora, humeris angulosa, lateribus extra apicem parum arcuata, apice conjunctim rotundata, 1 et 2/3 tam elongata quam simul in maxima latitudine lata; subtenuiter striato-punctata; striis ad apicem et ad latera attenuatis. Long., 2 mill.

Oblong, environ deux fois et demie plus long que large dans sa plus grande largeur, modérément convexe, brillant, couvert d'une pubescence flave-cendrée, fine, couchie et assez dense; brun de poix sur la tête et le prothorax, marron-testacé sur les élytres; bouche, pattes, et antennes plus claires. Antennes courtes, terminées par une massue de deux articles dont le premier est plus de deux fois plus large que long et dont le dernier, un peu plus long que large, est en forme de gland. Tête plus de deux fois plus large que longue, convexe, densement pointillée. Prothorax plus de deux fois plus large que long, arqué en avant, arrondi aux angles antérieurs, bisinué sur les côtés et finement rebordé, ou angles droits non émoussés aux angles postérieurs, subtronqué à la base, très finement rebordé aux extrémités, de celle-ci aussi densement, mais plus fortement ponctué que la tête. Elytres tronqués à la base, un peu plus larges que le prothorax, en angle non émoussés aux épaules, faiblement arquées sur les côtés, sauf vers l'extrémité très faiblement élargés, arrondis ensemble au sommet, environ une fois et deux tiers aussi longs que larges ensemble dans leur plus grande largeur, finement ponctués-striés; stries attenuées sur les côtés et à l'extrémité; intervalles des stries plans, finement pointillés. Stries marginales, des hanches intermédiaires s'écartant de la hanche pour rejoindre le bord interne de l'épimère metathoracique. Stries marginales des hanches postérieures s'avancant en angle obtus presqu'au milieu du segment; branche interne de l'angle prolongée presque jusqu'au sommet du segment. Portrine et abdomen finement alutacés.

Australie: Nouvelle Galles du Sud, Richmond River, 3 exemplaires envoyés par Mr. A. Lea.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. XI.—*Subdivision of the Spinal Canal in the Lumbar Region of Chick Embryos.*

By HELEN KELSEY.

(With Plate XLII.)

[Read 13th July, 1911.]

While examining serial sections of a chick embryo of about fifty-two hours' incubation, it was noticed that at the posterior end of the cord, in what would be the lumbar region of the adult, the central canal of the spinal cord was distinctly subdivided. At first this was regarded as an individual abnormality, but since then a large number of specimens have been examined, and the division has been found to occur invariably at a certain stage in the development of the embryo.

All the specimens were preserved in picro-sulphuric acid, subsequently stained with acetic acid, alum and carmine, and cut serially. The eggs used for incubation were procured from a number of different hens, and were incubated and examined during the springtime of three successive years, so that there is no reason to doubt that the development is normal.

Previous observers have described multiple canals and branchings of the central canal of the spinal cord in the chick (see Bibliography), but these are evidently different in nature from those now dealt with. In all cases they have been regarded as individual abnormalities and not, as certainly appears to be the case, as indicating a normal stage in the development of the spinal cord.

Then again, they occur at a much later date, when those now dealt with have completely disappeared. Miss A. Smith (1899), for example, describes them in a chick of 10 days' incubation, and as occurring far forward at the level of the heart and lungs. Federow (1907) describes them in a 5-6 days' chick.

In all those that I have examined, the maximum development occurs between the fifty-second and fifty-sixth hours. The period of subdivision extends from 48 to 58 hours' incubation.

Up to 42 hours the cord is unclosed and normal. At 44 hours, though the cord is closed in the lumbar region, there is no sign of any unusual development. At 48 hours the first sign of subdivision is seen in the form of a marked thickening and projection inwards of the wall on one side of the cord, the cavity, however, not being completely subdivided, although somewhat reduced.

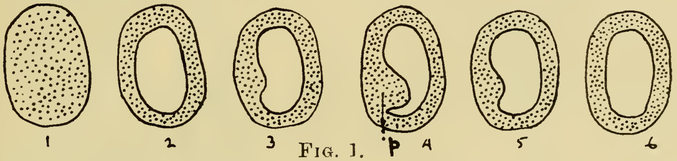


FIG. 1.

Text figure I. represents diagramatically five consecutive transverse sections of the cord at 48 hours' incubation. The projection (p) into the central canal (c) is well shown.

At 50 hours two distinct cavities are present, as seen in the figures. The projection may be seen to have grown completely across the cord in this region in such a way as to divide off the single central canal into two unequally-sized canals, c_1 and c_2 (see text fig. II., 2 and 3); this inequality of the resulting canals having been already suggested in the earlier stage by the peculiar shape of the internal projection of the wall of the cord. The total absence of any canal at the most posterior end of the cord is shown in section 1, fig. II.

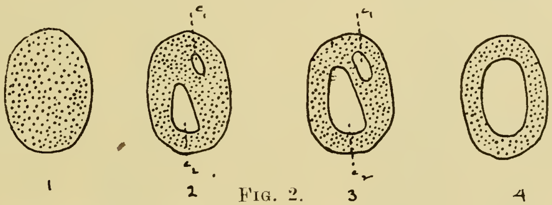


FIG. 2.

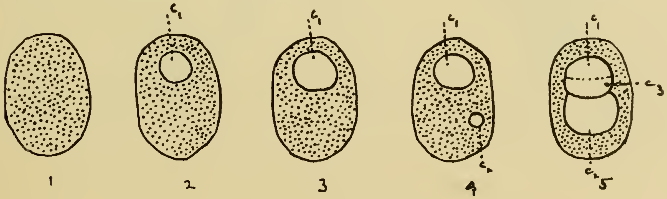


FIG. 3.

A little later, 51-52 hours, the two canals have become smaller though still unequal in size, as seen in text fig. III., 2, 3 and 4. The larger of the two (c_1) extends distinctly further back than the other, diminishing in size as it does so. At the extreme anterior end of this subdivision the septum between these two canal (c_1 and c_2) becomes very thin, and just at this part the larger canal (cf. plate XLII., fig. 3, and text fig. III., 5) shows a distinct though very thin septum, resulting in an incipient division into three canals.

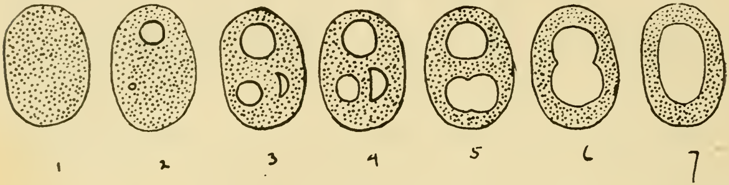


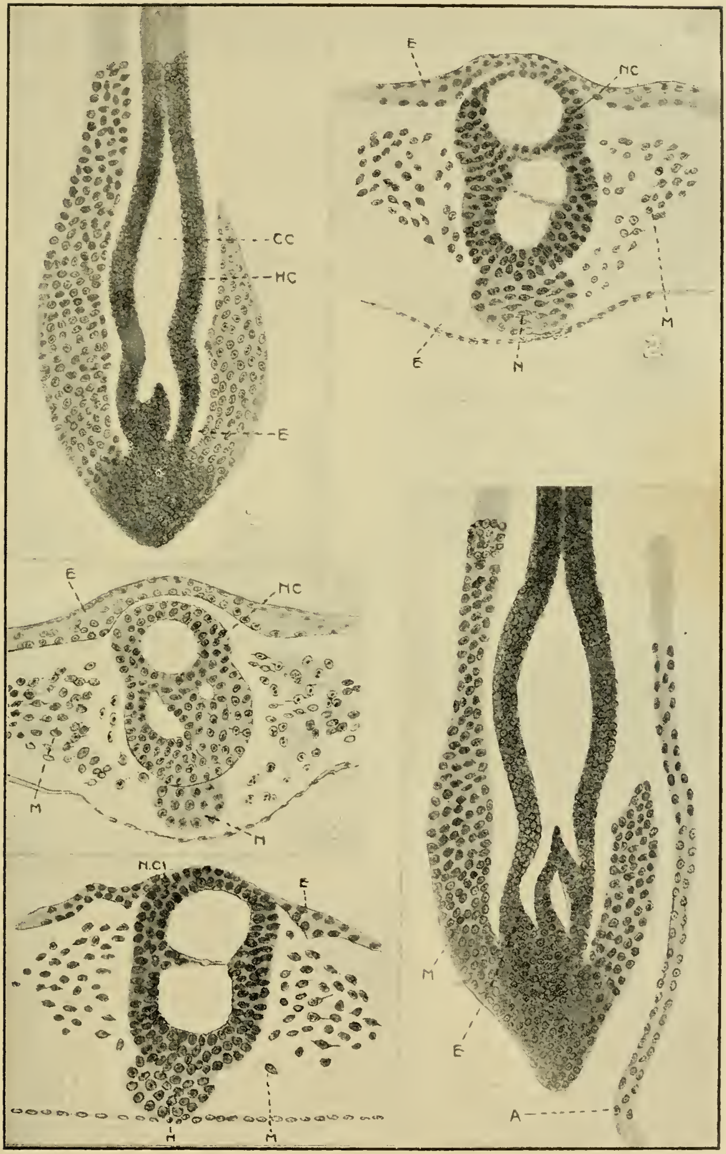
Fig. 4.

The complete division posteriorly of the central canal into three canals, as met with at 52-56 hours, is illustrated in text fig. IV. The inequality in transverse diameter and also in the longitudinal extension of the three canals is clearly seen. In most of the specimens examined three canals were distinctly visible; in several there were four, and in one instance an indication of a fifth canal was present.

The maximum extension of this subdivision is on an average 0.126 mm. in specimens of 52-56 hours' incubation. As might be expected, the lining of the several subsidiary canals is ependyma of precisely the same structure as the lining of the central canal proper.

The curious shape of the internal septa subdividing the central canal is clearly shown in sagittal section in Plate XLII., Figures 4 and 5, taken approximately at 56 hours' incubation, at which stage three canals are present. It will be seen, further, that the presence of these canals and the development of their divisional walls alter considerably the external configuration of the cord at the posterior end, causing it to become very much swollen, and often being constricted off from the general central canal.

I have not been able to determine exactly what happens to the spaces or the manner in which they close up, but this must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take place with some rapidity, as amongst the large number examined I have never seen a trace of subdivision after the fifty-eighth hour.

In conclusion, I wish to thank Professor Baldwin Spencer for his help and encouragement, and the use of his laboratory, and also to thank Dr. Georgina Sweet for the kind assistance she has given me.

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DESCRIPTION OF PLATE XLII.

Reference letters:—

a = amnion.
e = epiblast.
h = hypoblast.
m = mesoblast.
n.c. = nerve cord.
n = notocord.

Figs. 1, 2, 3.—Transverse sections of chick embryo at 56 hours, Fig. 1 being the most caudal and Fig. 3 the most cranial, showing the formation of the three canals in the nerve cord.

Figs. 4, 5.—Sagittal sections through a chick embryo at same stage as Figs. 1-3, showing configuration of nerve cord and character of the walls subdividing the original single canal into three.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. XII.—*Notes on the Geology of Broadmeadows.*

By F. L. STILLWELL, B.Sc.

(Kernot Research Scholar, University of Melbourne).

(With Plates XLIII.-XLIV.)

[Read 13th July, 1911.]

Introduction.

The area dealt with in this paper has been mapped by the Geological Survey of Victoria on the quarter sheet No. 2 S.W., and lies mainly in the parish of Will Will Rook, and the northern part of the parish of Tullamarine, in the County of Bourke. It includes the low granitic hill of Mt. Gellibrand and the valley of Broadmeadows.

The following stratigraphical horizons are met with:—

Post tertiary	-	Alluvium.
		Limestone.
Tertiary -	-	Newer basalt.
		Sands and quartzites.
		Older basalt.
		Clay bed.
Palaeozoic	-	Devonian.
		Silurian.

These will be considered in order, commencing with the oldest.

Physiography.

The area is drained by the Moonee Ponds Creek and tributaries, whose valley is separated by a basalt-capped ridge from the valley of the Saltwater River, two or three miles to the west. This ridge continues northwards and southwards, and the two valleys remain more or less parallel throughout their whole length till finally, still distinct, they enter the Yarra.

The township of Broadmeadows lies sheltered in the valley of the Moonee Ponds Creek, immediately above the confluence of the right and left branches. Below the township, the valley is walled on both sides by newer basaltic plains, where, with a depth of 150 feet and an average width of 25 chains, the sides have an average slope of 1 in 4. Here, then, the valley is geologically young, and similar to all others which have been carved out on basalt plains. The youthful character is emphasised by the steep grade of the tributary creeks. The small tributary in Section VI., Will Will Rook, with a length of little more than half a mile, has an average slope of 1 in 20.

Above the township, where the two stream courses mark the junction of the newer basalt and the palaeozoic sediments, the valley presents a little more mature appearance. Lateral erosion has proceeded at a more rapid rate in the sediments unprotected by a basalt cap.

The present valley of Broadmeadows is post newer basaltic. The basalt streams, which probably came from the north (1) flowed round the granite hill called Gellibrand's Hill, and probably never covered the whole of the area now mapped as silurian. In the development of the new drainage system consequent on the lava flows, the streams, here as elsewhere, have found their easiest course along the junction of the basalt with the older rocks. So we find the upper part of the stream courses practically outlining the boundaries of the newer basalt with the granite, with the older basalt and with the silurian rocks. Of these the silurian sediments are least resistant to denuding agencies, and hence, while we find the granitic hill still maintaining its relatively high altitude, the old silurian hill, which banked up against the granite, has been very largely worn away and now forms part of the hollow in which the town of Broadmeadows is situated. The thin skin of basalt which consolidated on the lower southern slopes of this old hill is also partly worn away, as is evidenced by the presence of a small oval-shape outlier of newer basalt within the fork of the two branches of the Moonee Ponds Creek. This suggests that the course of the creek onwards towards the south has been determined by a southern continuation of this old silurian ridge from Gellibrand's Hill.

SILURIAN.

This sedimentary series is here, as throughout the Melbourne district, the fundamental rock. It is found well exposed in the stream valleys and beds, and is represented on the map as covering a fairly large area. This area is mainly well-grassed country, but exposures here and there indicate its extent. It is bounded on the north by the granite, on the north-west by the older basalt, and elsewhere by tertiary deposits. Lithologically they consist of a series of sandstones and mudstones, and a few shales with a strike about 42 deg. E. of N. Observations of the dips lead to the statement that most of the area is part of two dissected anticlines whose axes are represented by the dotted line on the map. On the quarter sheet these rocks are noted as "yellow and white argillaceous sandstones, with mottled red, yellow and brown ferruginous beds and olive-coloured shales." It is also stated that "in places along the Broadmeadows Creek 8 to 10 feet of drift composed of angular fragments of granite, trap and silurian, rests on the above and passes upwards into the soil; slightly sandy nodules like orthoceratites and gasteropoda are found on both sides of the creek in the shales."

With regard to the precise age of these rocks there is no direct evidence, as no fossils were found in this area. Silurian fossils are recorded from Keilor, five miles to the S.W., and as the lithological characters and strikes approximately agree, we can assign a silurian age to the Broadmeadows series.

DISTRIBUTION AND GENERAL CHARACTERS OF THE GRANITE.

The granite hill of Gellibrand forms a prominent feature of the area. Being partially wooded, it stands out in contrast with the treeless basalt plains and the cultivated and well-grassed silurian country. Though only about 500 feet high, an extensive view may be had from the summit in several directions. To the south stretches out the city of Melbourne and the shores of Port Phillip. To the north-east lie the Plenty Ranges, and to the north, closer at hand, are low volcanic hills and other granite hills. To the north-west lies the distant mass of Mt. Macedon, with the outstanding plug of solosbergite, known as the Camel's Hump. More to the west lies Mt. Blackwood, and the Werribee Gorge may also be seen. To the south-west rises Mt. Cotterill amongst other volcanic cones, and further on the bold outstanding granite peaks of the You Yangs.

The granite hill is part of a more or less circular outcrop of granite which has been cut in two by a north and south lava stream, and is the nearest outcrop of a granite massif to Melbourne, apart from granitic dykes in Melbourne itself. This was no doubt one of the factors bearing on its use as a building stone for the old Princes Bridge, Chief Secretary's Office, and Town Hall.

As to its geological relations, along the southern margin it is represented on the map as being in contact with the silurian, but the exposures are very poor. In a small creek in Section VIII. Will Will Rook, which runs down from the granite hill, the silurian sandstone and granite can be found *in situ* within a short distance of one another. The sandstone preserves the general strike, and shows no alteration, but on examination is found to contain pockets of shale. In Section IX., in the first exposure of silurian rocks met with in following down the bed of the creek, the general strike is not so well preserved. The shale bands here show evidence of squeezing, and contain nodular concretions of harder rock. One of these nodules was sectioned. From another shale band which appeared to be very indurated another specimen was taken and sectioned. Both these sections approached the hornfels type. A specimen was also obtained from a loose boulder along the approximate boundary in Section VII. This, when sectioned, was also found to be a hornfels.

The evidence (though small in quantity) is therefore distinct as to the slight metamorphism of the silurian sediments by the intrusion of the granite. The granite is therefore post silurian, and correlating with the Victorian grano-diorites, as we are justified in doing by its chemical and petrological characters, we may consider it as devonian in age.

KAOLINISED GRANITE.

Along the creek in Section IX., Will Will Rook, is to be found a white face of kaolinised granite, exposed in a small gully about fifteen yards long. The outcrop, which does not reveal the extent of the material, is distinctly granite decomposed *in situ*, for there has been no resorting of the material. A rounded patch in the face contains much finer-grained material than the average, and represents a basic secretion in the original granite.

The material consists of unaltered, angular quartz with white mica set in white kaolin. The white mica and kaolin represent the secondary products of the original mica and felspar in the granite, while the quartz has remained unaltered. It is a question which cannot be decided on the available evidence, in what manner the change has been brought about. Such occurrences may be ascribed to subaerial agencies. Surface water and atmospheric carbon dioxide are capable of converting the alkalies present in the granite into carbonates which would be leached out, leaving a resultant product, chiefly kaolin and quartz. With regard to this it may be noted that the occurrence is very close to the contact of the basalt, and the conditions would be favourable to an excess of drainage along this junction. An alternative view is to regard the origin of the kaolin as due to pneumatolytic action of the emanations from the mass of cooling granite in its final stages of consolidation. This is the proved origin of kaolin deposits in Cornwall (2). The chief kaolinising agents in this case are shown by F. H. Butler (2) to be water and carbon dioxide. Fluorine and boron vapours often accompany them, and may result in tourmaline, fluorspar and topaz. Such minerals would most likely be concentrated along veins. No veins have been observed in the present case, and very little evidence is to be had for or against either theory. The pure white face and the abundance of white mica might lead one to lean towards the theory of a deep-seated origin.

Similar occurrence is found along the border of the granite outcrop at Bulla,[1] four or five miles to the north-west, and is the subject of a brief report by E. J. Dunn (3). The outcrop is of much greater extent, and the rock is spoken of as soft and crumbling, and consisting of ordinary quartz granules and kaolin, the latter replacing the felspars. He says it has been carted at heavy expense to Northcote and to Ringwood, and used successfully for fire bricks and for lining furnaces. This outcrop, being nearer to Melbourne, may therefore be of value.

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[1] Since writing the above, a discussion of the Bulla material has been published by Mr. R. W. Armitage, B. Sc. Vict. Nat., vol. xxviii., July, 1911.

ASSOCIATED DYKES.

In Section VIII., Will Will Rook, there occurs a line of boulders of quartz porphyry in the silurian country. The line is east and west, but is determined by a fence of a cultivated paddock. But it is evident that a quartz porphyry dyke occurs in the vicinity, which has shed these boulders in weathering. The rock consists of phenocrysts of quartz and felspar set in a very fine-grained ground-mass. The felspar has a rectangular outline, but is too decomposed to be retained in thin section. It is probable that this quartz porphyry dyke occurring so close to the contact of the silurian and granite is to be associated with the intrusion of the granite.

Chemical Characters.

A chemical analysis of this rock was carried out in April, 1909, at the Geological Laboratory of the Melbourne University, by Mr. H. S. Richards, M.Sc. The analysis has not been published hitherto, and it is Mr. Richards' generosity that makes it available now for discussion along with the petrographical characters.

The silica is lower, and the lime and magnesia higher than in a true granite. Still the total lime and magnesia is lower and the total alkalies higher than the Macedon grano-diorites. The total composition suggests that it is nearer to the adamellite type than the true grano-diorite. This suggestion is supported by the petrographical examination. The relative amounts of plagioclase and orthoclase were determined by a series of traverses across a rock slice, and it was found that the proportion of plagioclase to orthoclase was less than two to one. The position of the rock in the American system is—Class I., Persalane; Order 4, Brittanare; Rang 2, Toscanase; Sub-Rang 3, Toscanose.

Petrographical Character.

Megascopically the granite is a grey rock, coarse grained, and shows crystals of quartz, felspar and biotite.

Microscopically the crystallinity of the rock is seen to be holocrystalline, and non-porphyritic, with crystals of variable size. The average crystal size is medium, and the texture is hypidiomorphic. The minerals present are quartz, biotite, plagioclase, orthoclase, chlorite, muscovite, apatite, zircon, and magnetite. The quartz is allotriomorphic and contains inclusions of apatite and zircon.

The plagioclase is mostly idiomorphic. A zoned crystal without lamellar twinning has an extinction almost parallel to the trace of cleavage, thus indicating andesine. The zones become progressively more acid. The orthoclase is mostly untwinned and cloudy. The chief alteration product from the felspar is kaolin, but a little secondary white mica and calcite has also resulted.

Biotite is abundant in large and small ragged crystals, and contains inclusions of apatite, zircon and magnetite.

Green chlorite is abundant as a decomposition product of the biotite. Muscovite occurs in loose aggregates which appear to be secondary. Apatite is plentiful in small colourless crystals with low polarisation colours, which distinguish it from the less abundant, prismatic and pointed crystals of zircon with its high polarisation colours. The zircon also has a dark border.

Magnetite occurs in grains throughout.

The rock is not a true granite, differing from such in its content of andesine. It is not a true grano-diorite, since the plagioclase is not sufficiently predominant over orthoclase. It may be described as an adamellite bordering near a grano-diorite.

SUB OLDER BASALTIC ROCKS.

In section along the Moonee Ponds Creek below the older basalt quarry, a thin bed of about 2 feet is to be seen underlying the older basalt and resting unconformably on the silurian. It consists of a clay with much disseminated quartz grit, stained brown by iron solutions from the basalt. It is interesting in that it contains abundant material of what in the field appears undoubtedly fossil wood, but which on examination in the laboratory does not disclose cell structure. The cell structure may have been destroyed during the replacement of the organic material by limonite.

In the bed of the creek upstream from the quarry, decomposed older basalt may be seen above a clay containing quartz grit, which passes into a bed of more or less re-sorted kaolinised granitic material containing some white to brown mica. This in turn passes into a white clay. The observations are made in plan and are not too clear, and admit of two explanations. First that here, the only point in the district, we have an outcrop of a bed which may possibly be correlated with the lower tertiary leaf beds which underlie the older basalt at Royal Park (4) and elsewhere. Secondly, that the resorted granitic material is but a thickened part of the 2-foot bed observed lower down, which has not been so deeply ironstained, and that this in turn rests on a clay which is part of the silurian series.

DISTRIBUTION AND GENERAL CHARACTERS OF THE OLDER BASALT.

The older basalt occurs in an oblong-shaped area of undulating country to the west of Gellibrand Hill, and along the valley of the right branch of the Moonee Ponds Creek, in Sections VII., Will Will Rook, and XV. and XVI., Tullamarine.

The occurrence is the most northerly extension of the series which is found in Green Gully, Keilor, along the Saltwater at Sunshine, at Essendon, Moonee Ponds, Flemington and Royal Park. It is exposed on the hillsides and along the bed of the creek, but is best studied in some river cliff sections and in a quarry in the southern portion of the area. In this quarry the rock is perfectly fresh and shows a remarkably good columnar structure. The columns are best seen on the southern wall of the quarry, where they are well marked, though not so straight and clean cut as the newer basalt columns, known as the "Organ Pipes," near Sydenham; nor are they as high, being not more than 20 feet. On opposite walls of the quarry they are tilted in directions towards one another. On the N.W. face the columns are tilted at about 40 deg. to the vertical and at a much smaller angle on the opposite face. On the S.E. face the columns are in part vertical, and gradually pass into the inward sloping columns on both sides. The quarry therefore marks the site of a pre-older basaltic river valley. In a cliff section higher up the stream the columnar structure is again evident. Here in the upper part the columns are not so well defined, and in the lower part some of the columns are very small and more or less weathered. Still further up the stream the creek bed is formed of pavements or columns in plan. These are mostly hexagonal in outline, and frequently show irregular cracks, this being the first stage of their disintegration.

From the quarry a sample of the normal rock was taken, sectioned and analysed. From this fresh rock all stages in decomposition may be observed up to a soft, more or less iron-stained, wackenitic clay. In one section below the quarry the platy structure, and in part the spheroidal appearance, is developed, and at the bottom it is very soft and has the appearance of a red earth, which in the hand specimen has somewhat the appearance of a tuff.

As regards geological relations, its precise age cannot be determined in this area. It is clearly post silurian. Its relations with the tertiary quartzites will be discussed later. It occurs mostly at a lower level than the newer basalt, and though the two series come together in the northern part of the area, the two are not visible together in one section. Its chemical and petrographical characters show that it is distinct from the newer basalt, and that it may be correlated with the older basaltic series which has been shown to be in other parts barwonian (5).

Chemical Characters.

The analysis of this rock shows by the low percentage of SiO_2 its very basic character. The alkalies, totalling approximately 5 per cent., are greater than the average of the basalts for the SiO_2 percentage. This is impressed on one when working out the norm under the American system of classification, which brings an amount of nepheline into the composition of the rock. Its position in the classification is—Class III., Selfamine; Order 5, Portugare; Rang 3, Limburgase; Sub-Rang 4, Limburgose. The high percentage of combined water, 2.60 per cent., is notable, and finds expression in the large quantity of brown glass in the rock.

Petrographical Characters.

Specimen No. 24 was obtained from the older basalt quarry. Megascopically it is a very dark, hard and dense basalt which is rather brittle under the hammer. Crystals of olivine and a very occasional crystal of felspar can be observed in the hand specimen scattered throughout a dark-coloured matrix. The outer shell of the specimen contains no phenocrysts, and is distinctly more tachylitic. Microscopically the rock consists mainly of phenocrysts of olivine set with felspar laths and grains of augite in a ground mass of brown glass.

The olivine phenocrysts for the most part are clear and unaltered in imperfectly shaped crystals, though some good hexagonal and octagonal outlines may be seen. Some of these show simple and interpenetrative twinning. Stages in the alteration of the olivine to a yellow-brown mineral may be observed. This red-brown alteration product is more often seen than the intermediate stages, indicating that the change, once started, takes place very rapidly. This red-brown mineral corresponds with iddingsite, except that it is isotropic in the complete crystal. In the half-way stages it extinguishes in the same position as the olivine, and corresponds exactly with iddingsite.

The felspar is present in two distinct types. Most of the laths show lamellar twinning, and, in the measurement of the angle of extinction of the lamellae in a large number of sections, the maximum observed was 42 deg., while several values of 35 deg. were obtained. This felspar, then, according to the diagrams of Michel-Levy, is labradorite with the composition $Ab_3\ An_7$. One large phenocryst of this felspar is present. It is corroded by the magma and is crowded by black inclusions. It shows but a trace of the lamellae, and also shows cleavage, and is therefore a section almost parallel to (010). Its extinction angle measured from the trace of cleavage is 41 deg., showing that in composition it approaches pure anorthite. In addition to this basic felspar there is a tabular felspar which has wavy extinction and is untwinned or simply twinned. In ordinary light it is mostly clear and colourless, and where cleavage is present it is found to have a very low angle of extinction. It is mostly allotriomorphic, but in places the crystal outline is partly discernible, and then it shows a tendency to a rhombic outline. Application of the Becke method shows that it has a refractive index lower than that of labradorite. The microscopical evidence is therefore in favour of its determination as a soda-orthoclase or anorthoclase, and this conclusion is in perfect concordance with the chemical analysis..

The augite occurs as small grains and prisms intimately associated with the brown glass. Its colour is yellowish-brown, indicating a titanium variety.

Apatite occurs as minute inclusions in the felspar laths, and grains of ilmenite or magnetite occur throughout. Microlites which are opaque, and therefore probably ilmenite or magnetite, occur abundantly throughout the brown glass. Microlites of felspar and augite may, in addition, be seen.

Besides the above minerals there is present a pale green mineral which is isotropic. It shows in part a banded appearance, and is some form of secondary amorphous silica, probably hyalite.

The rock may be described as an olivine anorthoclase (?) basalt.

TERTIARY SEDIMENTARIES.

These consist of fine sands, hard quartzites and coarse and fine ferruginous grits. Many of the boulders of quartzite contain rounded pebbles of quartz embedded in them. The ferruginous grits often contain nodular concretions of limonite. The quartzites and grits occur as a fringe along the sides of the valley underlying the newer basalt. The unconsolidated sands are well exposed in a gully in Section XV., Tullamarine, which drains into the Moonee Ponds Creek. Lower down this same gully the quartzites may be observed.

Pipe-like concretions of limonite, which look like branches of trees, have been observed in the grits, but these, like those at West Essendon (8), show on examination no trace of plant structure.

These sediments clearly underlie the newer basalt, and are therefore older.

Ascending the right branch of the Moonee Ponds Creek the first of the newer rocks to be found in contact with the silurian is, omitting the sub older basaltic clay previously discussed, the older basalt in a decomposed condition, showing platy structure and spheroidal weathering. Immediately following this is an outcrop of quartzites which appear to come down to the level of the silurian. Then 50 yards or so further on, the older basalt comes in again in the columnar quarry. In one place on the side of the valley the older basalt appears vertically above the quartzite. We must therefore consider two possibilities:—

(1). Quartzites, etc., older than the older basalt.

(2). Quartzites, etc., newer than the older basalt.

(1). That this was probably the conclusion of the officers of the Geological Survey is evident from the index on the quarter sheet. The quartzites, etc., are called "older pliocene," and the older basalt "pliocene" simply. R. A. F. Murray, in his Geology of Victoria (6), has referred to the existence of quartzites underlying the older basalt, but does not give examples.

This theory involves the likelihood that all the quartzites, grits and sands are not of the same age, for the unconsolidated sands occur at a much higher level than any part of the older basalt, and immediately underneath the newer basalt. It would enable us to read the section in the bed of the creek above the quarry with more confidence as a sub older basaltic tertiary bed, and therefore as a non-silicified part of the same series as the quartzites.

The evidence is chiefly the apparent vertical distribution of the older basalt above the quartzites.

(2). In this case the quartzites are read as resting on a differentially eroded surface of older basalt, and any apparent contradiction occurs where the quartzite is not *in situ* and has suffered hill slip. All the quartzites, grits and sands can then be taken as belonging to one series, or two conformable series. This view receives all the support of correlative evidence.

Lithologically this series is similar to the series of quartzites and grits and sands of West Essendon (10), which rests unconformably on the older basalt (10). Mr. R. W. Armitage records marine fossils, and assigns them to the kalimnan (miocene) period.

Even with the correlation, it is an undecided question whether these beds are marine or fluviatile, i.e., whether the kalimnan sea extended as far north as Broadmeadows, or whether these deposits were laid down in a river flowing through Broadmeadows into the kalimnan sea. Exposures of the iron-stained material which is found to be fossiliferous at Royal Park and West Essendon are so poor in this area that any thorough search for fossils is impossible. The negative evidence is therefore not of much value.

NEWER BASALT.

The newer basalt is part of the eastern fringe of the extensive sheets of South-Western Victoria. Here it is part of flows which have come from the north, and possibly, according to T. S. Hart (1), from the low volcanic hills four or five miles to the north in the parish of Yuroke.

The newer basalt extends only as a thin capping which, as sections along the valley show, has flowed over almost level tertiary deposits. The surface of the flows is very scoriaceous, and the extent of this scoriaceous basalt indicates very little erosion since its consolidation. Still places are occasionally found where the basalt is in an advanced state of decomposition. This is usually assigned to ordinary processes of weathering which may have been localised in sundry ways. But it is more likely to have resulted from the chemical action, subsequent to consolidation, of enclosed magmatic waters and gases. That the magma contained large quantities of these is evidenced in the abundant material, chiefly arragonite, deposited on the walls of the vesicles.

Chemical Characters.

The rock analysed was collected from a point marked B on the map, and taken from the lower part of a small section along the river valley. According to the American classification the rock would be called:—Class I., Dosalene; Order 5, Germanare; Rang 3, Andase; Sub-Rang 4, Andose. The chief feature is the rather higher alkali percentage than that of the average of the 161 analyses of typical basalts collected by R. A. Daly (8). This finds expression in the petrographical description. The rather higher percentage of CO_2 does not mean that the rock is not fresh, but is explained by the presence of vesicles filled with arragonite.

Petrographical Characters.

Specimen No. 35 (B), Section VI., Will Will Rook. Megascopically it is a blue, even-grained rock in which crystals of green olivine, black augite, and felspar may be seen with the aid of a lens. A few vesicles may be seen lined with arragonite.

Microscopically it consists of phenocrysts of olivine, augite and felspar laths set in a ground-mass, partly felspar, partly augite, but mostly glassy.

The olivine crystals are often much altered in that along the edges and cracks the crystals have the appearance of iron staining. This iron-staining sometimes extends right across the olivine crystal, which then assumes the characters of iddingsite, dark-brown colour, slight pleochroism, and straight extinction.

The augite is developed in irregular plates or phenocrysts to a much less degree than olivine. It is occasionally twinned, and is of a very pale yellowish-green variety. The bulk of the augite is distributed as grains and prisms throughout the ground-mass. It is probably a titaniferous variety.

The felspar laths show lamellar twinning, and the measurement of the extinction angles of a large number of sections gives a maximum of 35 deg., indicating a labradorite of approximately the composition of Ab_2An_3. In addition there is another felspar with the same characters as the second type of felspar found in the older basalt, and therefore to be described as soda-orthoclase or anorthoclase.

Grains of magnetite or ilmenite occur scattered through the ground-mass, and minute prisms of apatite occur in the felspar laths.

The rock may be called an olivine anorthoclase (?) basalt.

Distribution and General Characters of Limestone.

The limestone occurs in a more or less irregular way along the valley of the left branch of the Moonee Ponds Creek. It occurs most extensively along a side gully and the bed of the tributary creek, from which it has been omitted from the quarter sheet. In places along the main stream—e.g., the point marked D on the map from which a specimen was collected and analysed, it may be observed to rest directly and unconformably on the folded silurians. It is not bedded, nor continuous, and is very variable in character. At the point marked C on the map, close to the boundary of the allotments X. and XIV., is a small excavation in the limestone rock from which a sample was taken and also analysed. Here it is a very hard, grey rock which weathers on the surface to a dull white, and which contains small disseminated quartz grains and scattered lumps and boulders of a scoriaceous and weathered basalt, such as is found on the surface of flows. At the locality D on the boundary of allotments IX. and XIV., it is of a white colour, much softer, and contains a great deal more quartz and other impurities. In addition to these two types there are many variations. It is found in every condition between the above and a black marl, when the percentage of admixed river silt is very large. In one section of creek alluvium it is found in the form of nodules in horizontal layers. This alluvial material is derived in part from the silurian rocks, in part from the basalt, and in part from the limestone, and therefore contains much magnesia. Rain water, on passing through, has partly dissolved out the lime and magnesia, and by means of the concretionary process has redeposited the carbonates in more or less horizontal rows of lenticular concretions.

Fresh-water shells are to be found enclosed in the limestone in the bed of the creek, and more abundantly in the tributary creek. A specimen was very kindly examined by Dr. Pritchard, who stated it to be *Pomatopyrgus buccinoides*, Quoy and Gaimard, a species which may still be obtained living in the creeks in great numbers. Dr. Pritchard also tells me that some of limestone patches are made up very largely of *Coxiella confusa*, E. A. Smith. The late Professor McCoy originally referred to material from this locality as containing *Truncatellas*, but Dr. Pritchard has not seen any of this genus, and is inclined to think that perhaps *Coxiella* was the shell referred to by Professor McCoy.

Previous References.

The rock at C is described on the quarter sheet as a "cherty limestone too hard and impure to be profitably burnt for lime," and "of recent tertiary age," and, further, that it contains "brackish-water shells (*Truncatella filosa*) and living species." Reference is made to it by A. R. C. Selwyn (8) in his "Descriptive Catalogue of Rocks and Minerals," among the older pliocene rocks. He calls it an impure limestone which probably contains much magnesia, and was formerly burnt for lime. He states that it occurs underlying the newer basalt, with tertiary quartzites and ferruginous grits. He also notes that it contains fossil shells (*Truncatella*), and an analysis (quoted below by J. C. Newbery) is recorded. The same rock is again referred to by G. H. F. Ulrich, F.G.S. (9), under the heading, "Dolomite (Magnesian Limestone)," when the above statement of the occurrence is repeated, with the addition that in the bed of the creek, below the outcrop of the band, occurs a similar rock that encloses *Truncatella*, and is most likely derived from the former.

Geological Relations and Origin.

Along the small gully at C, the limestone, outcropping at a lower level than the newer basalt, does give the appearance of a bed underlying the newer basalt. The included boulders of basalt, however, clearly show that the bed must be younger than the newer basalt, and the outcrop can only be considered as a superficial plaster on the side of the gully extending but a few feet inwards, and not, therefore, to be associated with the tertiary quartzites and grits which do underlie the newer basalt.

All the evidence, variability of composition, lack of bedding and continuity, and the presence of lime-encrusted boulders, points to a chemical rather than a mechanical origin. This chemical origin may be ascribed to magmatic waters and rain waters which, percolating through the basalt, have dissolved out some of the lime and magnesia and re-deposited it along the prominent joint planes, and these have determined the direction of the streams. Hence we should expect the limestone to be found in greatest quantity along those directions which were joint planes, and this is actually the case. The limestone in the main creek, whose direction has not been determined by a joint plane, has accumulated partly by the main process and partly as a secondary product derived from material deposited in joint planes. G. H. F. Ulrich's statement, then, that the rock in the bed of the creek is, most likely, secondary, is probably correct in part. The original limestone in the big joint planes, while being washed by streams and rain, would be partly dissolved and re-deposited in other parts of the stream course, and in this way the shells of organisms living in the stream, many of the basalt boulders, and quartz and felspar grains have become buried in it. The rock thus formed is of the same age as the river alluvium. It is probable that the hard, compact, grey rock, which may be observed to weather to a dull white rock, is the original limestone, and the whitish rock along the main creek is mostly a secondary deposit of the same age as the alluvium, and derived from the former either by weathering or by solution and re-deposition.

That the limestone has been deposited from solution, and, further, that the process is still going on, is evident from the fact that many of the stones in the creek have incrustations of lime, and that there are boulders of fresh basalt, up to three and four feet in diameter, partially cemented into the rock. We also find this, where the main stream flows directly over the silurian bedrock, filling up cracks and joint planes in a manner which could only result from deposition from solution.

Correlation with Similar Victorian Deposits.

I have not been able to find an account of a limestone of exactly similar nature in Victoria. An outcrop of a tertiary limestone occurs six miles away at Green Gully, Keilor, but this is marine (4). A fresh-water limestone at Malmsbury is reported in the Catalogue of Rocks and Minerals (9), and is stated to contain much magnesium carbonate and to represent a product of the decomposition of basalt. A magnesian limestone of fresh water origin occurs at Coimaidai, near Bacchus Marsh (14), but differs from the Broadmeadows occurrence in the thin clay and chert bands which traverse the limestone. W. H. Ferguson (12) considers it as probably laid down in a lake occupying a hollow in the glacial conglomerate. R. A. F. Murray (13) judges it to be tertiary in age, and of fresh-water origin, or else a spring deposit. It is reported as hard in some places, soft in others, and in others highly brecciated and mixed with ferruginous clay. It has valuable hydraulic properties, and on comparing the analysis by J. C. Newbery it is seen to contain much less silica and clay than the Broadmeadows stone.

A tertiary fresh-water limestone also occurs in the valley of the Duck Ponds Creek. Analyses (15 and 9) show that it is very variable and only magnesian in part. It is noted on the quarter sheet as a limestone which makes good building lime, and may be made into cement when mixed with a proper proportion of clay. From a comparison with these rocks one may draw the conclusion that the Broadmeadows rock is too limited in extent and too impure to be ever of much economic importance.

Chemical Characters.

From the nature of the supposed origin of this limestone, and also from the fact that associated with weathered parts of the newer basalt we often find that magnesite has separated out in hard nodules, we might expect to find great variation in the magnesia percentage. Further, where the limestone has been deposited in the creek we might expect great variation in the amount of material insoluble in acids. Such we do find.

Specimen No. 39, collected from D, contains about one-third of insoluble material. Specimen No. 38, collected from C, is much more uniform in composition, and the insoluble material scarcely amounts to one-sixth. In the rock analysed by J. C. Newbery it is very much less, and only 5.94 per cent. The exact locality from which this specimen was taken is not marked on the quarter sheet, and therefore not precisely known.

The three analyses agree in a notable quantity of magnesia, and this fact led Professor Skeats to suggest that a thin section should be stained in order to determine whether any dolomite existed. Accordingly thin sections were prepared and subjected to Lemberg's test. A few drops of a solution of aluminium chloride and logwood are applied to the surface of the slice, and allowed to stand for a few minutes. The dolomite is unaffected, but over the calcite a gelatinous precipitate of aluminium hydrate is formed, and this is stained purple with the logwood. The section is then mounted in glycerine jelly. No decided differentiation resulted with the impure rock from D; but the rock from C gave very interesting results.

Petrographical Characters.

Specimen No. 38, collected from C, Section X., Will Will Rook. Megascopically this is a very hard, fine-grained, greyish and earthy limestone. It is slightly cavernous, and the caverns appear to be lined with more crystalline material. Scattered throughout are small crystals of quartz and occasional felspar and fragments of igneous material.

Microscopically the bulk of the rock is a crypto-crystalline mass of earthy carbonate in which are set angular and sub-angular crystals of quartz and occasional felspar. Isolated lumps of igneous material contain lumps of plagioclase felspar and grains of olivine set in a brownish glass, thus indicating basaltic material. Along the cracks and caverns in the slice crystallisation has occurred, and this has been well brought out by the staining. The crystallised material is for the most part purple, and therefore calcite in very minute crystals. But in many of the cavities, most pronounced in those completely filled with crystalline material, only the inner part consists of calcite, between which and the wall of the cavity is a ring of unstained dolomite, which is well defined from the ground-mass.

The rock may therefore be described as a dolomitic limestone.

Specimen No. 39, collected from D, is, megascopically, rather a loosely compacted, whitish rock, which contains numerous pebbles of rounded and sub-angular quartz, felspar and basaltic material, set in a white calcareous material. The pebbles are very loosely set, and readily torn out on slicing.

Microscopically, it is seen to consist very largely of quartz pebbles, lumps of basalt, and felspar set in an exceedingly fine-grained ground-mass of calcareous material. Re-crystallisation has not proceeded at all, and very little was gained by staining.

The rock may be described as a detrital limestone.

ALLUVIUM.

The alluvium occurs in small quantity along the bed of the creeks. It is obviously derived partly from the granitic area, partly from the basalt, and partly from the silurian sediments. It is omitted from the accompanying map for the sake of clearness.

In conclusion, I should like to gratefully acknowledge the help of Professor E. W. Skeats and Mr. H. S. Summers, M.Sc., throughout the year 1910, when the work detailed in this paper was carried out. I am also indebted to Dr. Pritchard for information concerning shells from the limestone, to Mr. H. C. Richards, M.Sc., for the analysis of the granite, and to Mr. H. J. Grayson for the micro photographs. Mr. Grayson also gave valuable and greatly appreciated assistance in the preparation and staining of the rock slides.

Summary.

The Broadmeadows area includes a low granitic hill called Gellibrand's Hill, which gradually rises from a river valley to the south. The hill and valley are surrounded by a level basalt plain.

In the valley and central portion of the area a folded series of silurian sandstones, mudstones and shales outcrop. The granite is intrusive into this series. A chemical analysis by Mr H. C. Richards, M.Sc., and a petrographical examination prove that the granite is to be correlated with the devonian granodiorites of Victoria. In part the granite is kaolinised.

North-west of the Broadmeadows township occurs a volcanic series which rests, with only a thin intervening iron-stained clay bed, on both granite and silurian rocks. This series has been found chemically and petrographically related to the older basalt series of Victoria.

A tertiary quartzite and grit series is found underlying the newer basalt plain and outcrops along the valley walls. It is probably younger than the older basalt, but the relations are not clear.

The surrounding newer basalt forms the eastern fringe of the extensive volcanic plains of the Western District. It is petrographically described as an olivine anorthoclase (?) basalt.

In the valley and creek beds in the north-east portion of the area occurs a limestone. This limestone has an irregular distribution and shows great variability in character. It is imbedded and contains eroded boulders of newer basalt and shells of living organisms. It is therefore of recent age, and younger than the newer basalt, and has a chemical rather than a mechanical origin. Chemical analyses show that it is impure and highly magnesian, and a petrographical examination proves the presence of dolomite in small amount.

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13. Dunn, E. J.—Notes on some geological formations near Bacchus Marsh. Rept. and Stat. Dept. Mines, Vic., 31st Mar., 1890, pp. 26-27.
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Chemical Analyses.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	67.75	44.95	50.50	48.78	8.93	23.89	4.467	2.05
Al_2O_3	16.11	15.50	16.01	15.85	3.38	8.88		
Fe_2O_3	0.50	2.04	1.40	5.37	1.39	1.08	1.476	1.90
FeO	4.00	10.47	8.98	6.34				
MgO	0.79	7.43	6.13	6.03	12.75	12.85		
CaO	2.68	8.24	8.05	8.91	31.07	19.87		
Na_2O	2.60	3.04	3.00	3.18	1.81	2.68		
K_2O	3.42	1.98	2.02	1.63	0.63	0.71		
H_2O+	0.96	2.60	0.29	1.03	1.84	1.27		*
H_2O-	0.20	0.52	0.48	0.73				
CO_2	nil	0.18	0.68		38.04	27.94		
TiO_2	0.85	2.77	2.04	1.39				
P_2O_5	0.09	0.52	0.39	0.47				
MnO	trace	0.21	trace	0.29				
Total	99.95	100.45	99.97	100.00	99.84	99.17		
Sp. Gr.	2.68	2.91	2.86					
$CaCO_3$					54.91	33.34	54.974	55.00
$MgCO_3$					29.50	26.73	39.007	41.00
							99.924	100.00

* Water + loss = .05

I. Granite Quarry, Gellibrand Hill, Broadmeadows (analysed by H. C. Richards, M.Sc.).

II. Older basalt (A) Quarry, section xv., Tullamarine, County of Bourke.

III. Newer basalt (B), section vi., Will Will Rook, County of Bourke.

IV. Average of 161 analyses of typical basalts (largely olivine bearing), from various localities. R. H. Daly, Journ. of Geol., vol. xvi., 1908, p. 409.

V. Dolomitic limestone (C), section x., Will Will Rook, County of Bourke.

VI. Impure limestone (D), section xiv., Will Will Rook, County of Bourke.

VII. Impure limestone, section x., Will Will Rook, County of Bourke, analysed by J. C. Newbery. Descriptive Catalogue of Rocks and Minerals, National Museum (Selwyn), p. 57.

VIII. Limestone, Bacchus Marsh. Analysed by J. C. Newbery, Laboratory Report, 1890.

DESCRIPTION OF PLATES XLIII. AND XLIV.

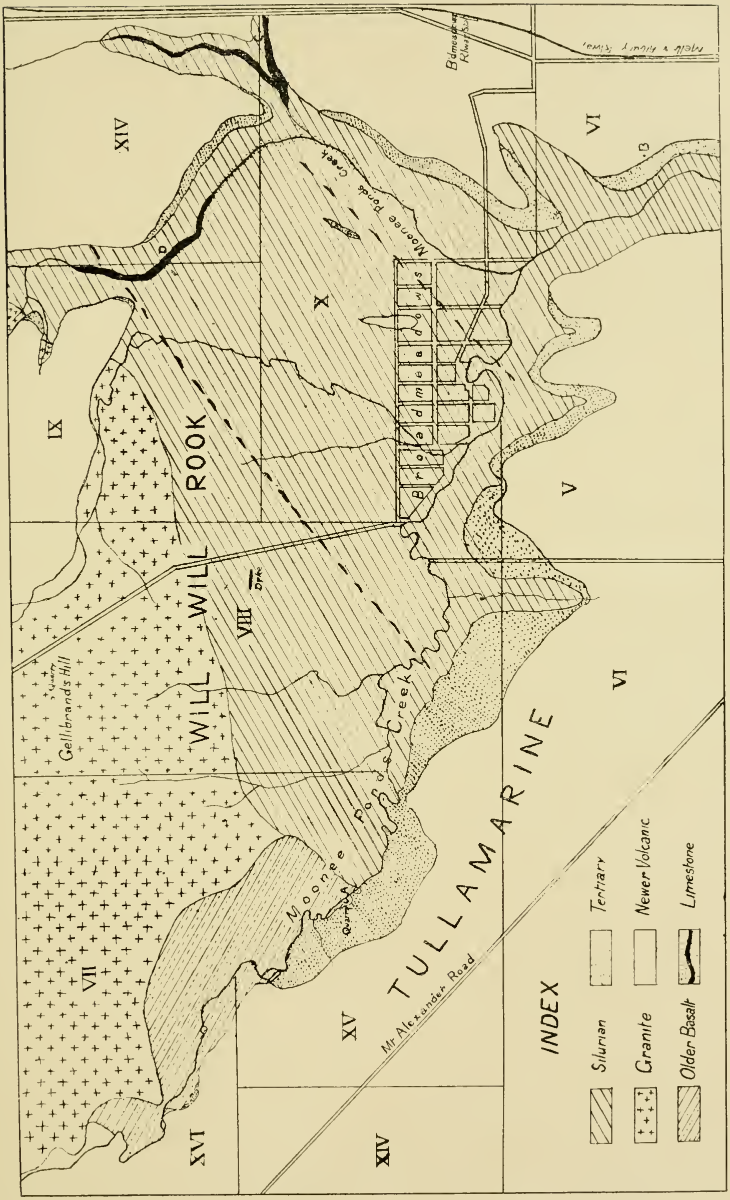
Plate XLIII.

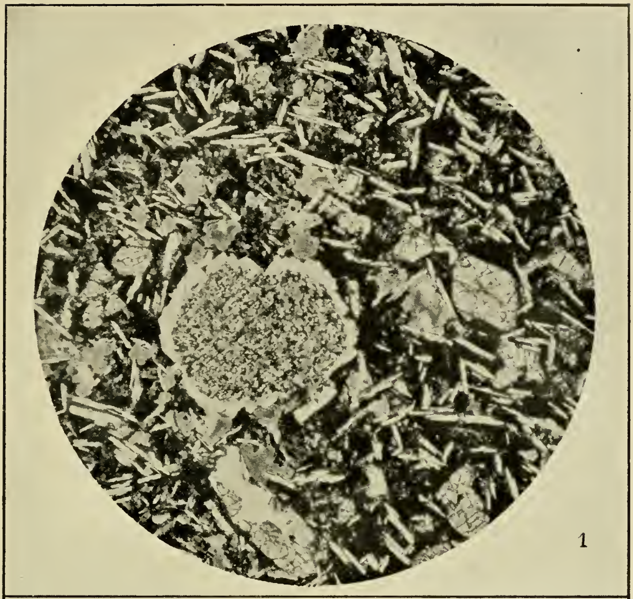
Map of Broadmeadows. Reproduced from the quarter-sheet No. 2, S.W., with slight modifications. Scale 2 inches to one mile.

Plate XLIV.

Fig. 1.—Olivine anorthoclase (?) basalt, older basalt series. The centre phenocryst is anorthite crowded with dark inclusions.

Fig. 2.—Olivine anorthoclase (?) basalt, newer basalt series. The olivine with its dark, altered border is in strong contrast to the clear olivine in fig. 1.


WILL WILL ROOK
TULLAMARINE
Moonee Ponds Creek
Moonee Ponds Creek
Broadmeadows
Broadmeadows Rlwy Stn
Melb & Albury Railway
Gellibrand's Hill
Quarry
Dyke
Quarry
Mt Alexander Road
B
XIV
IX
VII
XVI
X
VIII
V
VI
VI
XV
XIV
INDEX
Silurian
Granite
Older Basalt
Tertiary
Newer Volcanic
Limestone



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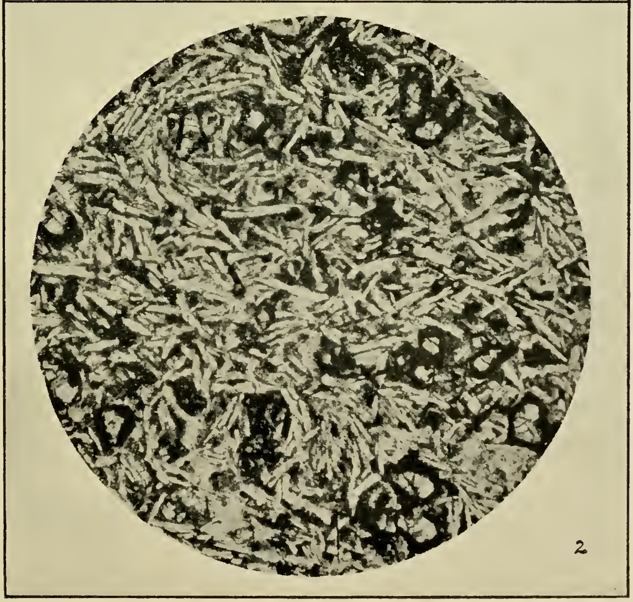

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Photo. micro. H. J. Grayson.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. XIII.—*New or Little-Known Victorian Fossils in the National Museum.*

Part XIII.—Some Silurian Species of the Genus Lingula; with Notes on its Shell-Structure and a Parasitic Plant.

By FREDERICK CHAPMAN, A.L.S., &c.
(National Museum, Melbourne).

(With Plates XLV.).

[Read 13th July, 1911].

Introductory Remarks.

Two species of the genus *Lingula* have been described from the silurian rocks of Victoria—viz., *Lingula spryi*, Chapman, and *L. yarraensis*, Chapm. (olim *L. latior*, Chapman non McCoy).[1] The present paper deals with four more species and varieties—*L. lewisii*, J. de C. Sowerby, var. *flemingtonensis*, var. nov.; *L.* cf. *striata*, J. de C. Sowerby; *L.* aff. *symondsi*, Davidson; and *L. perovata*, J. Hall.

Both divisions of the silurian in Victoria have afforded specimens of *Lingula*, but the genus is far more abundant in the lower, or melbournian, stage; only one species, *L. perovata*, occurring in the yeringian. The melbournian species agree to some extent with already known forms, ranging from the Upper Llandovery to the Upper Ludlows in Great Britain. The yeringian species now recorded occurs in the Niagara series (Wenlockian) of North America. *L. symondsi*, to which our passage-bed species seems related, has a fairly wide range in Great Britain, from the Upper Llandovery to the Lower Ludlow. The genus, as might be expected from the generally wide geological range of the different species in silurian strata, does not furnish any definite data as to zonal distribution, so far as can be gathered by comparison with the two widely separated areas of Europe and Australia. As a rule the shells of palaeozoic fossils in the Melbourne district are only indifferently preserved, but a marked exception is shown in *Lingula lewisii*, var. *flemingtonensis*, described below. In that varietal form something akin to the original colour still remains in the shell, accompanied by the dual structure of corneous and former calcitic layers, the corneous showing undoubted tubulated structure, in confirmation of Carpenter's researches.

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[1] *L. spryi*, Chapm., Proc. Roy. Soc. Victoria, vol. xvi., Pt. 1, n.s. (1903), p. 64, pl. x. figs. 9, 9a. *L. latior*, Chapm., op. cit., p. 65, pl. x., figs. 10, 10a; nom. mut. *L. yarraensis*, Chapm., op. cit., vol. xviii., Pt. 1, n.s. (1905), p. 19.

Lingula lewisii, J. de C. Sowerby, var. **flemingtonensis**, var. nov. (Pl. XLV., Figs. 1–5).

Description.—This variety is comparable in almost every way with the type species, the distinguishing characters consisting in the slightly broader aspect of the shell and its very distinct, radiate striae.

L. lewisii is described by J. de C. Sowerby[1] as " Oblong, compressed, smooth ; sides straight and parallel." Davidson, in his "Monograph of British Silurian Brachiopoda,"[2] describes it as with " surface nearly smooth, or marked with numerous concentric raised lines or ridges of growth, and here and there by more deeply indented striae." The figures given by both authors show faint radial or vertical striae. I have examined the shell-surface of two examples of *L. lewisii* in the National Museum collection, from Walsall and Sedgely in Staffordshire, and note that the striae thereon are distinct, fine, and generally interrupted by the concentric growth-lines ; whereas in the Victorian shells the striae are strong, continuous, and often deeply incised. In point of size the Victorian variety does not quite equal the European species, but is nevertheless by far the largest of the *Lingulae* in our silurian strata.

The largest Victorian specimen measures 23 mm. by about 16 mm., which is 7 mm. shorter than the English examples recorded by Davidson. The type species ranges practically throughout the silurian (? Upper Llandovery to Upper Ludlow) in Great Britain, where it has a wider range than any other species of the genus.

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[1] In Murchison's Silurian System (1839), Pt. II., p. 615, pl. vi., fig. 9.

[2] Pal. Soc., 1866, p. 35, pl. iii., figs. 1-6.

Occurrence.—Silurian (melbournian). Flemington ("Royal Park"). Coll. by the Geol. Survey of Victoria.

Note on the Shell-Structure of the Above Variety.

It is remarkable that an ancient brachiopod shell such as this should retain so much of its original structure; especially since it occurs in so unpromising a matrix. In appearance the shells, of which there are at least nine examples in the museum collection, resemble those of the recent corneous *Lingulae*, but are darker in colour. They vary from dark brown to almost purple black, and the colouring matter, which appears to be original, is organic, that is to say, carbonaceous. The surface of the shell has a dull sheen, resembling that of polished cow-horn, and under a tolerably high power is seen to be finely punctate.

As regards colouration, the palaeozoic *Lingulae* are, as a rule, devoid of colour, an exception being *L. symondsi*, as remarked by Davidson.[1]

The shell-structure of *Lingula* has been known through the work of Dr. W. B. Carpenter and M. P. Gratiolet. There are certain points in the descriptions by these two authors which are somewhat difficult to reconcile, and some further notes which I hope to publish later upon the structure of the recent and fossil examples may help to clear away these obscurities. It is sufficient to point out here that, whilst Carpenter[2] refers to the *Lingula* shells as being "almost entirely composed of laminae of horny matter, which are perforated by minute tubuli, closely resembling those of ivory in size and arrangement, and passing obliquely through the laminae," Gratiolet[3] has described the shell-structure in the living species—*L. anatina*, Lam.—as composed of several alternating layers of horny and calcareous material, the latter being vertically tubulated, and the horny layers devoid of any structure.

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[1] Mon. Brit. Sil. Brach. (Pal. Soc.), 1866 (1867), p. 34. " . . . none of the many fossil species hitherto collected throughout the entire sequence of sedimentary deposits, from the Lingula Flags upwards, have shown the smallest vestige of colour; unless, perhaps, *L. symondsi* from the Wenlock Shale."

[2] Rep. Brit. Assoc. (1844), 1845, p. 18, pl. ix., fig. 22.

[3] "Etudes anatomiques sur Lingula anatine (*L. anatina*, Lam.)." Journ. de Conchyl., vol. viii. (2nd ser., vol. iv.), p. 1860, p. 49.

In the silurian shells here described the sections are of a pale brown colour. A transverse section shows finely laminated structure on the broken edges of the slice. Under a high power the corneous layer is seen to be crowded with minute vermiform canaliculi. They are rather smaller, and more irregular than those in Carpenter's figure (fig. 22, loc. supra cit.), and agree with his example not only in their being set obliquely to the plane of lamination, but also in tending to branch, so that in the same focal plane both the orifices and lengths of the canaliculi are seen (fig. 4).

A vertical section of the fossil shell was made which, although somewhat thick, owing to its brittleness, shows an alternate, laminate structure quite clearly. The shell is of the same relative weight as that of a living example, and agrees in the number of laminae, which vary in relative thickness according to the part of the shell from which the section was taken. The stoutest layers in the silurian shell measure about .05 mm. in thickness.

The darker layers in this silurian fossil appear to represent the calcareous laminae, and the lighter layers the corneous. The altered calcareous laminae, when closely examined, show a few distinct traces of vertical tubes, especially towards the limiting surfaces of the layer. The corneous laminae are distinguished by an obliquely striated or fibrillate structure, very finely canaliculated, as in a living *Lingula* shell (*L. albida*, Hinds), which I have examined in specimens kindly given by Mr. C. J. Gabriel; although these layers are stated by Gratiolet to be structureless in the living *L. anatina*. Some of the horny layers of the fossil shell have been invaded by a parasitic boring fungus, the thallus of which shows a tendency to spread in the plane between two sets of laminae, but also penetrates to some depth into the shell.

This silurian *Lingula* shows no trace of carbonate of lime, this mineral having probably been leached out during the long process of fossilisation; but so gradually has been the replacement by other constituents that the intermediate horny layers are left undisturbed. In the living *Lingula* shell the proportion of carbonate of lime is very small, being 6.68 per cent., whilst the phosphate of lime is 42.29 per cent., and the organic matter 45.2 per cent.[1] It is therefore probable that the testaceous or calcareous layer is a phosphatised carbonate of lime, somewhat of the nature and composition of a crustacean carapace. My colleague, Mr. R. H. Walcott, F.G.S., has kindly tested this fossil shell, and obtained a decided reaction for phosphoric acid.

Description and Details of the Parasitic Fungus Previously Noted.

Tubes of thallus .02 mm. in diameter, filled with dark ferruginous matter, occasionally branched, and sometimes bearing a globular sporangium. Thallus either as single wandering cells or densely matted (see Plate XLV., fig. 6).

The branching thallus penetrates the shell between the horny layers. It may be provisionally referred to as *Palaeachlya* cf. *tortuosa*, Etheridge fil., a parasitic form described by Mr. R. Etheridge, jnr., from a Queensland carbopermian monticuliporid,[2] which has tortuous tubes with a diameter of .02 mm., and which exactly coincides with that of the present form. Another species, *P. torquis*, was described by the same author[2] from devonian corals *(Favosites)* of the Tamworth District, New South Wales; but this differs in having a more freely growing thallus, with slenderer tubes, of only half the diameter (.01 mm.).

Lingula cf. **striata**, J. de C. Sowerby. (Pl. XLV., Fig. 7).

(?) *Lingula striata*, J. de C. Sowerby, 1839, in Murchison's Silurian System, pt. II., p. 619, pl. VIII., fig 12. *Lingula striata*, Sow., Murchison, 1859, Siluria, p. 543, pl. XX., fig. 7. Davidson, 1886, Mon. Brit. Sil. Brach. (Pal. Soc.), p. 45, pl. III., figs. 45-48. This is a nearly perfect brachial valve, occurring in the blue mudstone of South Yarra, which in its sub-oval form, with squarish anterior margin, and distant, regular growth-lines or concentric striae, resembles very closely the above species. *L. striata* is a Lower Ludlow and Wenlock species in Great Britain. The present specimen is only one-third the length of the measurements of the described example of Davidson's, but the original of Sowerby's Aymestry specimens comes nearer, with a length of 11 mm. The South Yarra specimen has a black, carbonised appearance.

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[1] Gratiolet, op. cit., p. 62.

[1] Rec. Geol. Surv. N.S. Wales, vol. ii. 1891, p. 95, pl. vii., fig. 1.

[2] Rec. Austr. Mus., vol. iii., No. 5, 1899, p. 121, pl. xxiii., fig. 5.

Occurrence.—Silurian (melbournian). South Yarra (Yarra Improvement Works). Collected by Mr. F. P. Spry.

Lingula aff. **symondsi,** Davidson. (Pl. XLV., Figs. 8, 9).

Lingula symondsi, Davidson (Salter Ms.), 1866, Mon. Brit. Sil. Brach. (Pal. Soc.), p. 45, pl. III., figs 7-17.

The description of this species, given by Davidson, is as follows:—"Longitudinally oval or ovate, broadest about the middle, slightly tapering at the beaks, rounded in front; valves moderately and evenly convex, one valve a little more so than the other; surface smooth, marked only with fine concentric lines of growth. A large example measured—length 12, width 7 lines; but the shell is more often smaller."

The range of this species in Great Britain is from the Upper Llandovery to the Lower Ludlow. The specimen before us is a pedicle valve. It is roundly tapering towards the beak, rounded in front, moderately convex, and bears fine concentric lines of growth. Very faint radial striae can be observed under a lens in this Australian form, but since no other specimens are available it cannot be said whether the feature is distinctive. The fimbriate edges of the growth lines are probably due to weathering. In all other respects the shell is in close agreement with the British specimens. One British example of *L. symondsi* in the National Museum collection shows indications of radial striae on the worn surface of the valve.

Occurrence.—Silurian (probably passage beds between melbournian and yeringian). N.E. of Kilmore. Geol. Surv. of Victoria coll., locality Bb 24. The precise position is S.W. of Bald Hills, E. of Dry Creek and Kilmore. Collected by Norman Taylor, 10/11/57.

Lingula perovata, J. Hall. (Pl. XLV., Figs. 10, 11).

Lingula perovata, J. Hall, 1852, Pal., New York, vol. II., p. 55, pl. XX., figs. 3*a*, *b*.

The original description runs as follows:—

"Shell abruptly obovate, as wide as long, the base regularly rounded, and the sides much expanded; beak abruptly acute; surface marked by fine, rather distinct, elevated concentric lines; intermediate spaces smooth to the naked eye, but exhibiting under the magnifier fine, scarcely elevated, concentric lines."

The present example is a pedicle valve, from the yeringian sandy mudstone of Merriang Road, near Whittlesea.[1] It is somewhat damaged on the median area, but shows the outline clearly, and part of the ornament, consisting of distinct, distant ridge-like striae, not crossed by radial lines. The interspaces between the concentric striae are marked by fine concentric lines exactly as in the North American specimens. Prof. J. Hall's examples came from the Upper Green Shale of the Rochester stage, which forms part of the Niagara series (Wenlockian).

The only other species which closely approaches this form in its regularly subtriangular shape is *L. roualti*, Salter,[2] from the Budleigh Salterton Pebble-beds (? ordovician). However, the radial striae serve to distinguish it from the present example.

Hall and Clarke, in their monograph on the Palaeozoic Brachiopoda,[3] draw attention to the fact that the acuminate type of *Lingula* prevailed both numerically and specifically in the earlier faunas and persisted until carboniferous times. It is not represented in the living species of the genus.

Measurements.—Length, 4.75 mm.; width, 5.25 mm.

Occurrence.—Silurian (yeringian). Merriang Road, section 3, near Whittlesea. Found and presented by Mr. J. T. Jutson.

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[1] Recorded as (?) *Lingula* by the writer in J. T. Jutson's "The Silurian Rocks of the Whittlesea District." Proc. Roy. Soc. Victoria, vol. xxi., Pt. I., n.s. (1908), p. 221.

[2] Quart. Journ. Geol Soc., vol. xx., 1863, pl. xvii,, figs. 4, 5. Also Davidson, Mon. Bil. Brach. (Pal. Soc.), 1866, p. 40, pl. I., figs. 14-20. Idem, Quart. Journ. Geol. Soc., vol. xxvi 1870, p. 76, pl. iv., fig. 2.

[3] Geol. Surv., State of N. York. Palaeontology, vol. viii., pt. i. 1892, p. 5.

EXPLANATION OF PLATE XLV.

Fig. 1.—*Lingula lewisii*, Sow., var. *flemingtonensis*, var. nov. Silurian (melbournian). Moonee Ponds Creek, Flemington. Geol. Surv. Coll. Nat. size.

Fig. 2.—*L. lewisii*, Sow., var. *flemingtonensis*, var. nov. Portion of shell of another specimen, showing the deep radial striae; also the irregular character of the concentric growth lines. Silurian (melbournian). Moonee Ponds Creek, Flemington. Geol. Surv. Coll. × 3.

Fig. 3.—Ditto. Vertical section of the shell (external surface beneath), showing the pale horny layers, the dark, altered intermediate layers, and also traces of a parasitic boring plant. Same locality. × 52.

Fig. 4.—Ditto. Thin flake of shell parallel and close to surface, showing minute canaliculi permeating the horny shell substance. (Diagrammatic). Same locality. × 380.

Fig. 5.—Ditto. Portion of vertical section of shell shown in figure 3, more highly magnified, with fibrous horny layer below *(a)*, surmounted by the original calcareous layer *(b)*. × 100.

Fig. 6.—Ditto. A flake from the horny layer of shell, probably near visceral surface, perforated by boring fungus. Same locality. × 60.

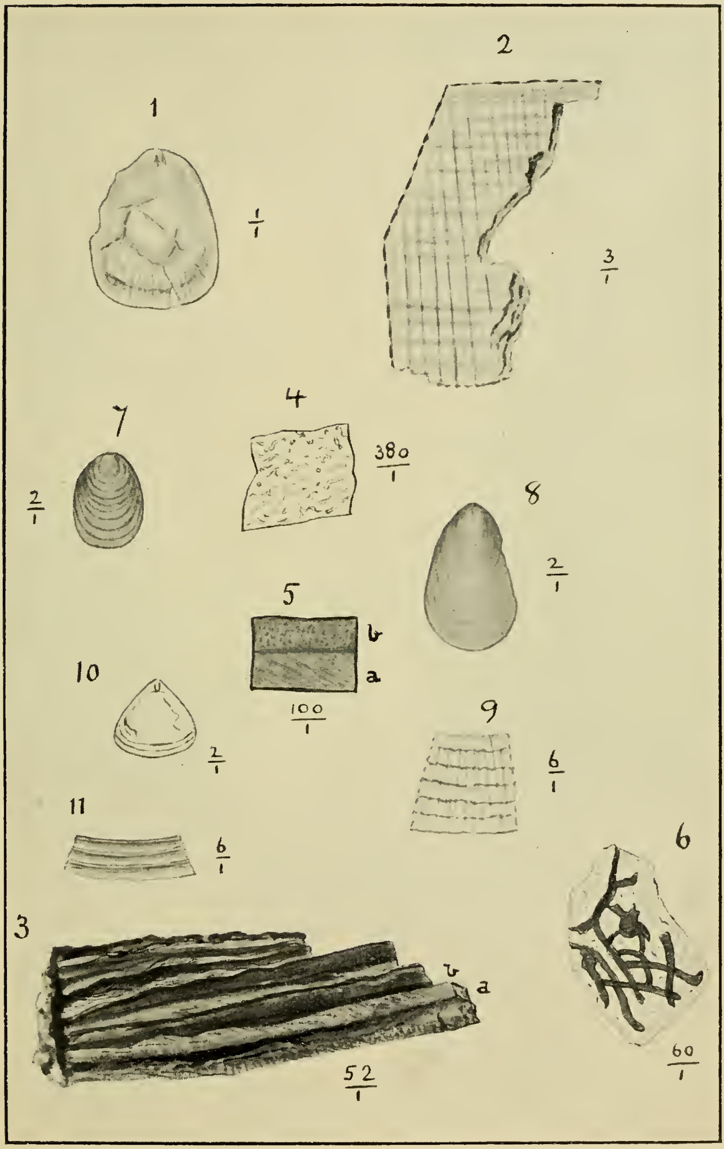
Fig. 7.—*Lingula* cf. *striata*, Sowerby. Silurian (melbournian). South Yarra. Coll. F. P. Spry. × 2.

Fig 8.—*L.* aff. *symondsi*, Sow. Silurian. N.E. of Kilmore. Coll. Norman Taylor. × 2.

Fig. 9.—Ditto. More highly magnified surface of same shell, showing the fimbriated concentric growth lines, and faint radial striae. × 6.

Fig. 10.—*L. perovata*, J. Hall. Silurian (yeringian). Merriang Road, near Whittlesea. Coll. J. T. Jutson. × 2.

Fig. 11.—Ditto. Portion of shell surface more highly magnified, showing ridge-like growth lines and intermediate striae. × 6.



F.C. ad nat. del.

Shells and Shell-Structure of Silurian Lingulae, Victoria.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. XIV.—*On some New Species of Victorian Marine Mollusca.*

By J. H. GATLIFF and C. J. GABRIEL.

(With Plates XLVI.-XLVII).

[Read 13th July, 1911.]

The present paper describes one new genus and eight new species, figures of which are also given.

We are again indebted to Mr. E. C. Joshua for his skilful photographs, from which the plates have been prepared.

Aclis pellucida, sp. nov. (Pl. XLVI., Fig. 4).

Shell acicular, white, semitransparent, longitudinally ribbed. Whorls eleven, rounded, gradually and regularly increasing in size. Apex rounded; the first two whorls are smooth, the remainder are crossed by numerous fine rounded threads, which run in a slightly oblique direction from left to right; the interspaces are about the same breadth as the threads; under the lens there is an indication of faint spiral threads on the lower whorls. Suture well defined. Mouth ovate. Outer lip joins at the centre of the body whorl. Columella regularly curved to the axis of the shell.

Dimensions of Type.—Length, 4.0; breadth, 0.82 mm.

Locality.—Dredged between Phillip and French Islands, Western Port, in about six fathoms. Port Albert (T. Worcester).

Obs.—This delicate little shell in general appearance resembles *Turbonilla fusca*, A. Adams, but is much smaller and narrower.

Type in Mr. Gatliff's collection.

Odostomia victoriae, sp. nov. (Pl. XLVI., Fig. 2).

Shell elongate, acicular, white. Whorls nine, exclusive of the heterostrophe protoconch. The whorls are slightly convex, and appear to be smooth, but under the lens numerous slight encircling incised lines are discernible, that at the periphery of the body whorl being well defined. Suture incised. Mouth ovate. Outer lip sharp. Inner lip slightly everted. There is a moderately strong ascending columellar-plait, situated well within the mouth.

Dimensions of Type.—Length, 7 ; breadth, 2.60 mm.

Locality.—Port Albert (Thos. Worcester).

Obs.—A thin vitreous shell of a regularly tapering form.

Type in Mr. Gatliff's collection.

Turbonilla portseaensis, sp. nov. (Pl. XLVI., Fig. 1).

Shell milky-white, solid, imperforate. Sutures well defined. Whorls nine, including a produced, two-whorled, heterostrophe protoconch. They are rounded, slightly shouldered, straightly, longitudinally ribbed, the penultimate bearing about twenty-two. These ribs are prominent, shining, just project at the shoulder, and continue to the base, where they cross a faint carination, gradually vanishing as they approach the columella. They are separated by deep interstices of similar breadth. Close, uniform, interstitial, spiral striation further ornaments the whorls. The basal interstices are similarly striate, the striae of base and body-whorl being more numerous than those on the preceding whorls. Aperture ovate, inner lip slightly reflected. Outer lip acute.

Dimensions of Type.—Length, 4.5 ; breadth, 1.5 mm.

Locality.—Portsea (type) ; Shoreham.

Obs.—A graceful form, milky-white colour, and ornate sculpture. The interstitial striation serves as a useful recognition mark, and in this respect somewhat recalls *Odostomia kreffti*, Ang.

Type in Mr. C. J. Gabriel's collection.

Jeffreysia wilfredi, sp. nov. (Pl. XLVI., Fig. 3).

Shell oblong-ovate, white, vitreous, thin, smooth, transparent. The axial pillar may be plainly seen. Whorls four, tipped with a broad, dome-shaped apex ; they are ventricose, and rapidly increase, the body-whorl occupying about three-fourths of the shell. Sutures impressed. If microscopically and transparently viewed, faint irregular ridges will be seen to encircle the whorls crossed by feeble lines of growth. Aperture about half the length of shell, ovate, rounded anteriorly. Peristome thin, entire, inner lip slightly reflected, behind which appears a slight umbilical chink.

Dimensions of Type.—Length, 2; breadth, 1 mm.

Locality.—Ocean beach, near Point Nepean.

Obs.—A small, transparent, rissoa-like shell. The specimens show variation, one being slightly larger than the type, its much rounder body-whorl comprising about four-fifths of the shell. Very few species of genus *Jeffreysia* exist, and it is interesting to note its occurrence in Australian waters, where, as far as we know, the present is the first record. This genus was placed by Alder in the family *Littorinidae.* Named in honour of the author's son, Wilfred E. Gatliff.

Type in Mr. C. J. Gabriel's collection.

Lucina mayi, sp. nov. (Pl. XLVII., Figs. 8-12).

Shell creamy-white, flatly convex, subequilateral. Beaks small, acute, slightly elevated. Lunule elongate and well defined. Escutcheon long and narrow, impressed. Sculpture of fine, sharp, concentric lamellae, with much wider interspaces, which become closer as they approach the ventral margin. Radial sculpture comprising irregular riblets, plainly seen under the lens, which traverse the concentric interspaces. Both valves present these features. On the right valve a shallow flexuosity is observed at the posterior dorsal area. The concentric lamellae continue to the post-dorsal margin. Hinge normal, muscular impressions well defined, with the pallial line easily discernible.

Dimensions of Type.—Length, 9; breadth, 8; depth of single valve, 1.75 mm.

Locality.—Dredged off Point Cook, Port Phillip, about eight fathoms.

Obs.—The species has not been obtained by us in pairs, opposite valves of similar dimensions being selected as the type. It has an ally in *L. brazieri*, Sow., from which it differs in the possession of radial sculpture and much sharper lamellae. One valve exceeds the type measuring 11 x 10 mm. Dedicated to the esteemed Tasmanian conchologist, Mr. W. L. May.

Type in Mr. C. J. Gabriel's collection.

Edenttellina, n. g.

Shell small, flattened, broadly ovate, inequilateral, posterior side longer and broader, hinge-line short, without teeth. Shining outside, and inside vitreous. Thin and fragile. Right valve only has an incurved projection of a rounded form just over the umbone, and directed to the front; it overlaps the left valve.

Type *E. typica*, Gatliff and Gabriel.

Edenttellina typica, sp. nov. (Pl. XLVI., Figs. 5-6).

Shell small, flattened, broadly ovate, very inequilateral, posterior side longer and broader. Slightly convex. Translucent, yellow. Slight irregular concentric sculpture. Posterior side somewhat swollen, dorsal margin arched. Shining outside and vitreous inside. Thin and fragile. The right valve only has an incurved projection of a rounded form proceeding from the umbone, it forms a coil, and overlaps the left valve. Ventral margin nearly straight. Hinge line short, without teeth.

Dimensions of Type.—Ant. post. diameter, 3.; dorso-ventral diameter 1.9 mm.

Locality.—Portsea, Port Phillip, (type) Ocean Beach, Point Nepean; Shoreham.

Obs.—We have not yet obtained the species in pairs, valves of similar dimensions being utilised as the type. We have obtained odd valves from other localities on our coast, during a period extending over more than ten years, some being of about twice the dimensions of the type, but in poorer condition.

Another species of the genus has been dredged off Hope Island, North Queensland, by Mr. C. Hedley. It is larger, broader, and not so inequilateral. We refrain from describing it, as Mr. Hedley desired to reserve to himself the description of shells obtained during that expedition.

Type in Mr. Gatliff's collection.

Cuna planilirata, sp. nov. (Pl. XLVII., Figs. 13-17).

Shell small, white, glossy, rather inflated, subequilateral, aequivalve, semitransparent. Beaks prominent. Prodissoconch small, smooth. Dorsal margins straight, ascending so as to almost form a right angle. Ventral margin much rounded. Lunule and escutcheon elongate and inconspicuous. Valves sculptured with numerous, close, concentric ridges, which are flattish, and continue to the ventral margin, this sculpture being clearly seen from within. Muscle scars evident. The pallial line, owing to the transparency of the shell, is not easily followed, but may be observed in worn specimens. Inner margin not denticulate.

Dimensions of Type.—Length, 2.50; breadth, 2.25; depth of single valve, 1 mm.

Locality.—Dredged between Phillip and French Islands, Western Port; about 5 fathoms.

Obs.—In general contour and ornament the species somewhat recalls *Neolepton antipodum*, Filhol, but is immediately separable by the hinge characters. The shell varies in colour, specimens of a pinkish hue having been obtained. The present one adds another species to our scanty representation of the genus. The genus, erected by Hedley in 1902, includes many species from Australian waters, and embraces such extreme forms as *C. praecalva*, Hedley, and *C. hamata*, Hedley and May. The generic location of small bivalves has in many instances proved a matter of considerable difficulty, and we think the diversity of characters allowed and described in many species of *Cuna* by the author of the genus will enable us to class under it some shells which we have hitherto been unable to place. The hinge characters alone show great variation, and this species is no exception, the cardinal tooth, though triangular, being very elongated.

Type in Mr. C. J. Gabriel's collection.

Montacuta nitens, sp. nov. (Pl. XLVII., Fig. 7).

Shell minute, white, shining, very inequilateral, smooth, swollen at the umbones, which are inconspicuous and situated near the front, equivalve.

Dimensions of Type.—Anterior-posterior diameter, 1.5 ; dorso-ventral diameter, 1.15 mm.

Locality.—Ocean beach, Flinders (type) ; San Remo.

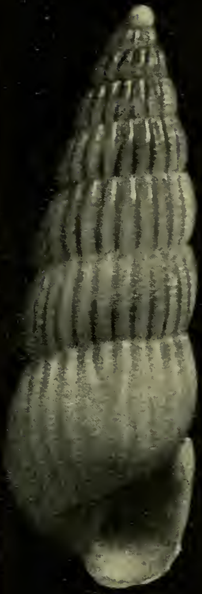
Obs.—This is a simple, minute, white shell of rounded-oval form.

Type in Mr. Gatliff's collection.

EXPLANATION OF PLATES XLVI. AND XLVII.

Fig. 1.—Turbonilla portseanensis, sp. nov.
2.—Odostomia victoriæ, sp. nov.
3.—Jeffreysia wilfredi, sp. nov.
4.—Aclis pellucida, sp. nov.
5.—Edenttellina typica, sp. nov., exterior.
6.—Edenttellina typica, sp. nov., interior.
7.—Montacuta nitens, sp. nov.
8 and 9.—Lucina mayi, sp. nov., interior.
10 and 11.—Lucina mayi, sp. nov., exterior.
12.—Lucina mayi, sp. nov., sculpture.
13.—Cuna planilirata, sp. nov. Exterior of type.
14 and 15.—Cuna planilirata, sp. nov. Interior of another specimen.
16 and 17.—Cuna planilirata, sp. nov. Exterior of figs. 14 and 15.

All of the figures variously magnified.



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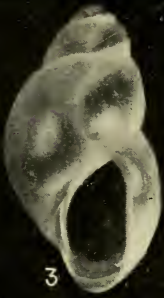

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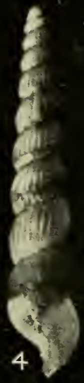

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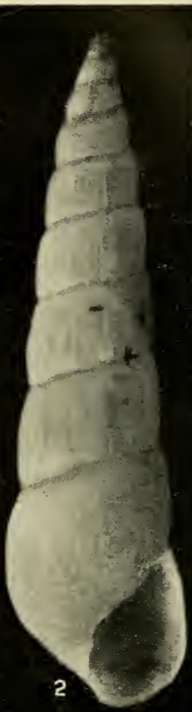

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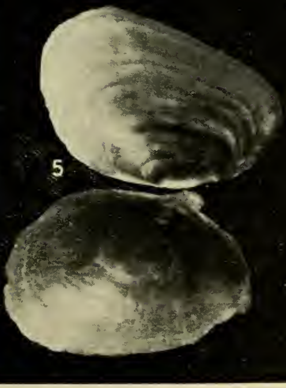

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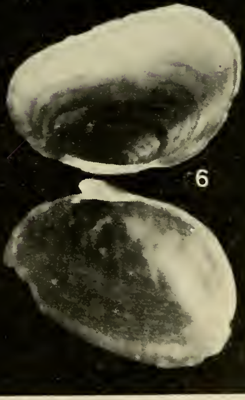

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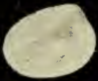
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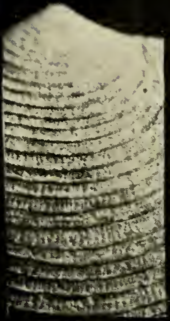
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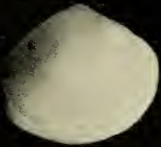
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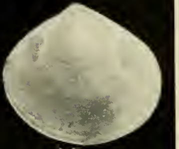
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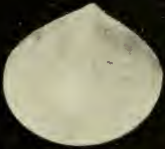
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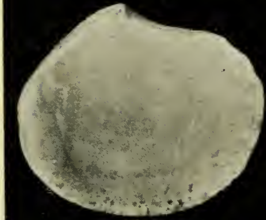
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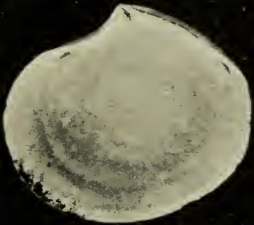
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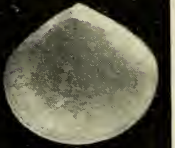
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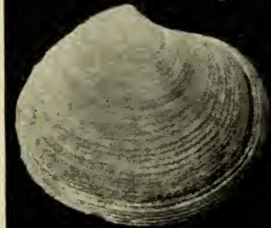
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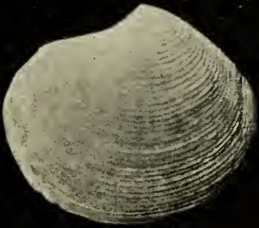
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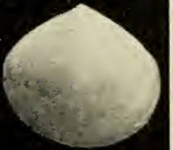
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[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. I., 1911.]

Art. XV.—*Additions to and Alterations in the Catalogue of Victorian Marine Mollusca.*

By J. H. GATLIFF and C. J. GABRIEL.

[Read 13th July, 1911.]

This paper includes the new genus *Edenttellina*, and the following genera new to Victoria, *Jeffreysia* and *Theora*, and deals with 28 species, 8 of which are new, 12 are additional species and 8 of the names are altered. The total number of species catalogued now reaches 940.

We have again to thank our good friends, Mr. C. Hedley, of the Australian Museum, Sydney; Dr. J. C. Verco, of Adelaide; and Mr. W. L. May, of Tasmania, for their kind assistance.

On plate 19 in the last volume of these Proceedings the numbers of figures 8 and 9 were reversed. That of 8 is *Cingulina rhyllensis*, and 9 is *C. magna*. A proof of the plate was not submitted to us.

Coralliophila wilsoni, Pritchard and Gatliff.

1897. Coralliophila wilsoni, Pritchard and Gatliff. Proc. Roy. Soc. Vict., vol. x. (n.s.), p. 140.
1901. Coralliophila rubrococcinea, Melvill and Standen. P.Z.S. Lond., p. 401, pl. 21, f. 2.

Obs.—The above species was described from an immature shell. Mr. Hedley has drawn our attention to a series of specimens connecting it with *C. rubrococcinea*, Melvill and Standen. The latter species will therefore become a synonym.

Coralliophila lischkeana, Dunker.

1882. Rapana lischkeana, Dunker. Index Moll. Mar. Jap., p. 43, pl. 1, f. 1, 2, and pl. 13, f. 26, 27.
1903. Purpura sertata, Hedley. Austr. Mus. Mem., vol. iv., p. 382, f. 95, 96.
1906. Purpura sertata, Pritchard and Gatliff. Proc. Roy. Soc. Vict. (n.s.), vol. xviii., p. 44.

1906. Coralliophila lischkeana, Hedley. Records Austr. Mus., p. 219.

Hab.—Port Albert (Thos. Worcester).

Obs.—The above correction is necessary, as it has been made by Mr. Hedley.

NASSA GRANDIOR, Verco.

1908 Arcularia grandior, Verco. T.R.S., S.A., vol. xxxii., p. 344, pl. 15, f. 16, 17.

Hab.—In 300 fathoms, 30 miles south of Cape Nelson, Commonwealth trawler "Endeavour."

Obs.—Size of Type: Length, 32.5; width, 15 mm.

MARGINELLA CONNECTANS, May.

1911. Marginella connectans, May. P.R.S. Tas., for 1910, p. , pl. 14, f. 11.

Hab.—Dredged Western Port in six fathoms; Port Albert (T. Worcester).

Obs.—Size of Type: Length, 3; breadth, 1.7 mm. Resembling *M. shorehami.* Pritchard and Gatliff.

COLUMBELLA PLURISULCATA, Reeve.

1859. Columbella plurisulcata, Reeve. Conch. Icon. vol. xi., pl. 36, f. 233.

1902. Columbella plurisulcata, Pace. P. Mal. S. Lond., pp. 83 and 122.

1906. Columbella filosa, Pritchard and Gatliff. Proc. Roy. Soc. Vict., vol. xviii., n.s., p. 48.

1908. Pyrene plurisulcata, Hedley. P.L.S., N.S.W., vol. xxxiii., p. 457.

Hab.—Western Port.

Obs.—Mr. Hedley states that a sinistral individual was taken by Brazier in Sydney Harbour.

COLUMBELLA CALVA, Verco.

1910. Pyrene calva, Verco. T.R.S., S.A., vol. xxxiv., p. 143, pl. 29, f. 2, 3, *Hab.*—Off Wilson's Promontory, Commonwealth trawler "Endeavour."

Obs.—In our last paper referring to this shell we stated that from the worn specimens that we had, we considered it to be a variety of *Pyrene gemmulifera*, Hedley. Dr. Verco has obtained many examples in good condition, and considering it to be a valid species, has named it as above.

COLUMBELLA BEACHPORTENSIS, Verco, var.

1910. Pyrene beachportensis, Verco. T.R.S., S.A., vol. xxxiv., p. 139, pl. 29, f. 8, 9.

Hab.—San Remo.

Obs.—Size of Type: Length, 4; breadth, 1.8 mm. Nearly related to *C. angasi*, Brazier. Our single specimen is not typical, and we therefore at present consider it to be a variety.

TURRITELLA OPULENTA, Hedley.

1907. Turritella opulenta, Hedley. Records Australian Mus., vol. vi., p. 292, pl. 54, f. 9.

Hab.—Off Wilson's Promontory, Commonwealth trawler "Endeavour."

Obs.—Size of Type: Length, 6; breadth, 2 mm. A very ornate little species.

TURBONILLA BEDDOMEI, Petterd.

1884. Chemnitzia beddomei, Petterd. Jour. of Conch., vol. iv., p. 136.

1886. Turbonilla tasmanica, Tryon (non T. Woods). Man. Conch., vol. viii., p. 335, pl. 76, f. 40.

1892. Turbonilla crenulifera, Tate. T.R.S., S.A., p. 126, pl. 1, f. 2.

1894. Turbonilla scalarina, Braz. P.L.S., N.S.W., vol. ix. (2nd series), p. 170, pl. 14, f. 5.

1898. Turbonilla beddomei, Tate. T.R.S., S.A., p. 85.

1900. Turbonilla tasmanica, Pritchard and Gatliff (non T. Woods). Proc. Roy, Soc. Vict., vol. xiii. (new series), p. 149.

Hab.—Western Port.

Obs.—Examination of the type of *Turbonilla tasmanica*, T. Woods, shows that is an undecollated *Truncatella* of the species *T. scalarina*, Cox; references are made thereto by Tate and May,[1] W. L. May[2] and J. H. Gatliff.[3]

An error was made by some of the earlier Tasmanian conchologists in wrongly identifying *T. beddomei*, Petterd, as being *T. tasmanica*, T. Woods, and one of them sent one of these wrongly indentified specimens to Tryon, who figured it, hence the subsequent confusion.

TURBONILLA PORTSEAENSIS, Gatliff and Gabriel.

1911. Turbonilla portseaensis, Gatliff and Gabriel. Ante page 188.

EULIMELLA AURANTIACA, Angas.

1867. Styloptygma aurantiaca, Angas. P.Z.S. Lond., p. 112, pl. 13, f. 14.
1886. Eulimella aurantiaca, Tryon. Man. Conch., vol. viii., p. 313, pl. 74, f. 40.
1901. Eulimella aurantiaca, Tate and May. P.L.S., N.S.W., vol. xxxiii., p. 383.

Hab.—Shoreham; San Remo (T. Worcester); Western Port.

Obs.—Tate and May place *Eulima aurantia*, Petterd, as a synonym. Specimens sent to one of us from Tasmania as being Petterd's species had a plait on the columella, and consequently it has been already catalogued as a synonym of *Pyramidella tincta*, Angas, a shell of very similar appearance.

ACLIS PELLUCIDA, Gatliff and Gabriel.

1911. Aclis pellucida, Gatliff and Gabriel. Ante page 187.

ODOSTOMIA LAEVIS, Angas.

1867. Odostomia laevis, Angas. P.Z.S., Lond., p. 112, pl. 13, f. 10.
1886. Odostomia laevis, Tryon. Man. Conch., vol. viii., p. 362, pl. 79, f. 67.

Hab.—Dromana, Port Phillip (T. Worcester); Kilcunda.

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[1] P.L.S. N.S.W., 1901, vol. xxvi., p. 390.
[2] P.R.S. Tas., 1902, p, 111.
[3] Vict. Nat., 1905, vol. xxii., p. 14.

ODOSTOMIA VICTORIAE, Gatliff and Gabriel.

1911. Odostomia victoriae, Gatliff and Gabriel. Ante page 187.

Genus **Jeffreysia**, Alder, 1849.

JEFFREYSIA WILFREDI.

1911. Jeffreysia wilfredi, Gatliff and Gabriel. Ante page 188.

TRIPHORA NIGROFUSCA, A. Adams.

1851. Triphoris nigrofuscus, A. Adams. P.Z.S., Lond., p. 278.
1867. Triphoris nigrofuscus, Angas. Id., p. 208.
1903. Triphora nigrofusca, Hedley. P.L.S., N.S.W., vol. xxvii., p. 611, pl. 33, f. 34, 35.

Hab.—San Remo, Western Port.

Obs.—Size of Type: Length, 4 lines. A black-brown species. Our single specimen is not quite typical, and may be considered to be a variety.

TRIPHORA ANGASI, Crosse and Fischer, var. leuca, Verco.

1909. Triphora angasi, Crosse and Fischer, var. leuca, Verco. T.R.S., S.A., vol. xxxiii., p. 282.

Hab.—Western Port.

Obs.—A white variety, but sometimes faintly brown, occasionally banded with that colour. "Usually longer and narrower than the typical shell."

TRIPHORA INNOTABILIS, Hedley.

1903. Triphora innotabilis, Hedley. P.L.S., N.S.W., vol. xxvii., p. 608, pl. 32, f. 23-25.
1909. Triphora innotabilis, Verco. T.R.S., S.A., vol. xxxiii., p. 283.

Hab.—Off Wilson's Promontory, Commonwealth trawler "Endeavour."

Obs.—Size of Type: Length, 4.8; breadth, 1.4 mm.

TRIPHORA DISJUNCTA, Verco.

1909. Triphora disjuncta, Verco. T.R.S. S.A., vol. xxxiii., p. 292.

Hab.—Dredged between Phillip and French Islands, Western Port.

Obs.—"Resembling *T. tasmanica*, T. Woods, in its apex, but with rather wide sutural spaces." Colour, light brown. Mr. W. L. May, in P.R.S., Tasmania, for 1910, records this species, and remarks, "Probably a variety of *T. tasmanica*, T. Woods."

TRIPHORA FESTIVA, A. Adams.

1851. Triphorus festivus, A. Adams. P.Z.S., Lond., p. 278.

1865. Triphorus festivus, Angas. Id. p. 172.

1901. Triforis festiva, Tate and May. P.L.S., N.S.W., vol. xxvi., p. 387.

1909. Triphora festiva, Verco. T.R.S., S.A., vol. xxxiii., p. 288.

Hab.—Portsea, Port Phillip; Anderson's Inlet.

Obs.—This species much resembles *T. maculosa*, Hedley, but it is smaller, more pupaeform, and differs in the protoconch.

BITTIUM TURRITELLIFORMIS, Angas.

1877. Bittium turritelliformis, Angas. P.Z.S., Lond., p. 174, pl. 26, f. 14.

1900. Seila attenuata, Hedley. P.L.S., N.S.W., vol. xxv., p. 91, pl. 3, f. 9, 9a.

1906. Seila attenuata, Pritchard and Gatliff. Proc. Roy. Soc. Vict., vol. xviii. (n.s.), p. 60.

1908. Bittium turritelliformis, Hedley. P.L.S., N.S.W., vol. xxxiii., p. 488.

Hab.—Ocean beach, Point Nepean. Dredged about 6 fathoms, Western Port.

Obs.—Mr. Hedley states that his *Seila attenuata* is the same shell as *Bittium turritelliformis*, Angas.

Genus **Theora**, H. and A. Adams, 1858.

THEORA FRAGILIS, A. Adams.

1855. Neaera fragilis, A. Adams. P.Z.S., Lond., p. 226.
1902. Theora fragilis, Hedley. P.L.S., N.S.W., vol. xxvi., p. 706.

Hab.—Dredged in eight fathoms, living, off Point Cook, Port Phillip.

Obs.—This is the first record of the genus occurring in our waters, so we give above the name of the author. Our examples range in size up to 12 mm. in length.

LUCINA MAYI, Gatliff and Gabriel.

1911. Lucina mayi, Gatliff and Gabriel. Ante p. 189.

ERYCINA PARVA, Deshayes.

1855. Kellia parva, Deshayes. P.Z.S., Lond., p. 82.
1902. Erycina acupuncta, Hedley. Mem. Austr. Mus., vol. iv., p. 321, f. 60.
1906. Erycina acupuncta, Pritchard and Gatliff. Proc. Roy. Soc. Vict., vol. xviii. (n.s.), p. 68.
1906. Erycina parva, Hedley. Trans. N.Z. Inst., vol. xxxviii., p. 73.

Obs.—Mr. Hedley notes that this shell was previously named by Deshayes.

MONTACUTA NITENS, Gatliff and Gabriel.

1911. Montacuta nitens, Gatliff and Gabriel. Ante p. 191

EDENTTELLINA TYPICA, Gatliff and Gabriel.

1911. Edenttellina typica, Gatliff and Gabriel. Ante p. 190.

CUNA PLANILIRATA, Gatliff and Gabriel.

1911. Cuna planilirata, Gatliff and Gabriel. Ante p. 191.

CYCLOPECTEN FAVUS, Hedley.

1902. Cyclopecten favus, Hedley. Mem. Australian Museum, vol. iv., p. 305, f. 50.

1904. Cyclopecten nepeanensis, Pritchard and Gatliff. Proc. Roy. Soc. Vict., vol. xvii. (n.s.), pp. 338 and 265, pl. 20, f. 5; and vol. xix., 1906, p. 4, pl. 2, f. 11.

1908. Cyclopecten nepeanensis, Hedley. Rec. Aust Mus., vol. vii., p. 113.

Hab.—Type locality of *C. nepeanensis*, Ocean Beach, Point Nepean. Also dredged in about 8 fathoms between Phillip and French Islands, Western Port.

Obs.—As was stated when the description of *C. nepeanensis* was published, prior to the shell being described as new, specimens were sent to Mr. C. Hedley (on 28th March, 1903, for him to retain), and he said it was new to him, so it was described as new. Recently he states that it is identical with his *C. favus;* one of us having examined his type, we are convinced that they are the one species. *C. nepeanensis* therefore becomes a synonym.

END OF VOLUME XXIV., PART I.

[PUBLISHED SEPTEMBER, 1911]

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XVI.—*The Psychrometric Formula.*

By E. F. J. LOVE, M.A., D.Sc., F.R.A.S.
(Lecturer on Natural Philosophy, University of Melbourne),

AND

G. SMEAL, B.Sc.
(Government Research Scholar).

MARINE BIOLOGICAL LABORATORY
WOODS HOLE, MASS.
LIBRARY

(With Plate XLVIII.).

[Read 14th September, 1911.]

The formula employed by Regnault for the wet-and-dry bulb hygrometer, or psychrometer, has been generally adopted, viz.:

$$x = f - A\,B\,(t - t'),$$

where x and f are respectively the actual pressure of water-vapour in the air, and the saturation pressure at the temperature t' of the wet-bulb. But Ekholm[1], of Sweden, has suggested modifying this formula by the insertion of a "hygroscopicity factor" η, to allow for a supposed diminution of the maximum pressure at the wet-bulb due to the hygroscopic nature of the material covering it. The formula as modified becomes:—

$$x = \eta f - A\,B\,(t - t'). \qquad \eta < 1.$$

Firstly, it may be stated that it seemed to us, on a careful examination of Ekholm's paper, that the grounds for the theory are very slight. Its importance, however, is great enough to justify a careful discussion. It appears to have been suggested by the well-known difficulties attending the use of the psychrometer at temperatures below zero, when the wet-bulb becomes coated with ice. In these circumstances it is necessary to use a value of A different from that used when the water on the bulb is fluid, and observation confirms the theoretical result that the two values should be in the inverse ratio of the latent heats of ice and water. Regnault noticed that the ice exerts a hygroscopic effect in very humid air, causing condensation on its surface, and other observers since his time have confirmed this. To allow for it, suggestions have been made for a correction of the observed value of either *t* or *t'*. Ekholm proceeds a step further by stating that the hygroscopic action of the ice is accompanied by a similar action of the material on which the ice is deposited, this latter action therefore varying with the nature of the material employed. He performed some experiments in which two wet-bulb thermometers coated with different stuffs were enclosed with a dry bulb thermometer in an air-tight vessel; sufficient water was poured in to form a layer on the bottom, and the whole maintained at a temperature below zero. The wet-bulbs, being coated with ice, and in contact with air nearly or completely saturated with water-vapour, received heat by condensation of vapour, and indicated higher temperatures than the dry bulb. This, of course, is due to the fact, unknown to Regnault, that the vapour-pressure of ice is less than that of water at the same temperature. The results of the observations are given as follows:—

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[1] Ekholm, "Ueber das Psychrometer," Arkiv. för Mat. Astron. och Fysik, Stockholm, 1908, Bd. 4.

Dry Bulb.	Wet Bulb.	
	Cotton.	Wool.
– 4.05	– 3.83	– 3.85
– 4.0	– 3.88	– 3.85
– 4.0	– 3.88	– 3.85
– 4.02	– 3.86	– 3.85
	Cotton.	Linen.
– 3.8	– 3.48	– 3.65
– 3.8	– 3.48	– 3.6
– 3.8	– 3.48	– 3.7
– 3.8	– 3.48	– 3.65
	Cotton.	Silk.
– 3.6	– 3.28	– 3.35
– 3.5	– 3.13	– 3.2
– 3.55	– 3.20	– 3.27

From these the conclusion is drawn that the condensation varies with the material, or that the material exerts a differential hygroscopic effect. Assuming the air contained in the vessel to be saturated, and adopting a value for the constant A given by Regnault for a closed space, the values of η to be used in the formula are calculated—viz.:

Linen - - - -	1.000
Silk - - - -	0.967
Wool - - - -	0.947
Cotton - - - -	0.944

From other considerations the value of η for linen is regarded as more probably 0.9737; in that case the air cannot have been saturated, and the list becomes—

Linen - - - -	0.9737
Silk - - - -	0.940
Wool - - - -	0.921
Cotton - - - -	0.918

Now it is at once evident that these observations are much too few to serve as a basis for any theory. It seems certain that they were not reliable to the hundredth of a degree, and it is only in the case of cotton and linen that any definite difference appears. (Special attention was paid to these two materials, which are the ones most commonly employed in meteorological work.) It is not, however, our intention to criticise these results themselves, but the conclusions which Ekholm, starting from them, reaches for the psychrometer in general. At such low temperatures as this the vapour-pressures are very small, and the instrument consequently insensitive; so we must agree with Ekholm's own remark that systematic observations in cold countries with thermometers graduated in hundredths of a degree are needed before the question of the behaviour of the psychrometer below zero can be satisfactorily discussed and settled.

The modified formula thus obtained is applied by its author to the observations of Regnault[1] and Svensson[2] for temperatures both above and below zero. Thus Regnault's seventh series was taken with the thermometer covered with cotton muslin and iced. In order to represent his observations with reasonable accuracy, he found it necessary to use two values of A over different ranges—viz., 0.00075 up to 70 per cent., and 0.0013 above 70 per cent. humidity. Ekholm finds that the single formula—

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[1] Regnault, "Etudes sur l'hygrométrie," Ann. Chim. Phys., 1853, 3 sér. vol. 37.

[2] Svensson, "Untersuchungen des Assmannschen Psychrometers," Meteor. Zeitschr., 1896, p. 201; Bihang till Kongl Svenska Vet.-Akad. Stockholm, 21, 1896.

"Zur Kenntnis des ventilierten Psychrometers," Akad. Abhandlung, Stockholm, 1898. The observations discussed are in the second paper.

$$x = 0.932 f - 0.000496\,B\,(t - t')$$

satisfactorily agrees with the whole set of observations, the values of the two constants η and A having been determined by least squares. If, however, Regnault had correctly interpreted his observations by using ice-pressures instead of water-pressures for f, the superiority of the Ekholm formula would not be so striking. The latter employs his own revised tables of vapour-pressures throughout.

Svensson's observations range from about $-3°$ to $+26°$ in dry temperature, and from 5 per cent. to 95.5 per cent. in humidity. For the temperatures above zero, the formula takes the value—

$$x = 0.9737\,f - 0.000596\,B\,(t - t').$$

Assuming the value of η to be the same whether the material—in this case linen—be covered with water or ice, and reducing the value of A in the theoretical ratio 600 : 680 of the latent heats, the formula appropriate to the lower temperatures becomes

$$x = 0.9737\,f - 0.000526\,B\,(t - t').$$

This is shown to be in good agreement with the observations, thus apparently confirming the suppositions made.

The same value of η is found to be suitable to Regnault's fourth series of observations, temperatures ranging between 7° and 30°, and a slightly different value, 0.968, to the ninth series, which Regnault regarded as taken in specially unfavourable circumstances.

The argument then rests on the two facts that the modified formula provides a better agreement between the calculated and observed values than the old one; and, secondly, that the value of η which does this is always a proper fraction.

Theoretical Discussion.

The natural answer to these arguments is that they provide no proof whatever of the truth of the new theory, since they are only what we should expect from our knowledge of the conditions and theory of the psychrometer. The formula

$$x = f - A\,B\,(t - t')$$

is admittedly only a first approximation, but one which is found in practice to give sufficiently accurate results, provided the value of A is regarded as empirical, i.e., it is to be determined by actual experiment for the special conditions under which the instrument is to be used. It might conceivably be improved in many ways; one that has been tried is the addition of a term $C\,(t - t')^2$, and this is if anything supported by Svensson's results,[1] since he found the value of A to depend somewhat on that of $t - t'$, being larger for low values of $t - t'$ than for high. But any change in the formula which introduces two arbitrary constants in place of one would, *ceteris paribus*, be likely to increase the accuracy with which it could represent a set of observations. The test of the real value of such an alteration is its correspondence with an actual physical condition, without which we have no certainty that it will apply even approxmately to any other than the particular observations from which it is deduced. In the case in question, we conceive that it has not been proved that the proposed factor η corresponds to an actual definite physical phenomenon, but on the contrary that our observations disprove it.

The second fact, that the value of η as obtained from the observations discussed is consistently less than unity, so far from demonstrating the presence of a hygroscopic action, is also to be expected from theory, as will be seen by consideration of the assumptions underlying the formula. In the usual theory it is supposed that the air is moving past the bulb in such a way that it becomes completely saturated at the temperature t', but does not receive a sensible amount of heat from the surroundings while it is in contact with the bulb. If either of these conditions is not fulfilled, the result will be the same as a diminution of f. And in this connection it is to be noticed that Regnault's work was done under conditions which are now recognised to be extremely unfavourable to the right use of the psychrometer. Much of it was carried out in closed spaces where no air-motion was possible, and the effects of radiation from surrounding walls would be a maximum; two of the series discussed by Ekholm, the seventh and the fourth, were taken under these conditions. In other cases the exposure to winds was very different in different directions, and in one case, the ninth series also discussed, which was taken on a high plateau in the Pyrenees, there was practically no shelter from wind at all. Modern practice proceeds on the understanding that moving air is almost essential, but that efficient shelter is to be provided from the direct action of the wind, hence the use of screens such as the Stevenson pattern. In some forms artificial wind is provided. Thus Svensson's work was done with an Assmann ventilated psychrometer,[1] a steady flow of air being maintained by a centrifugal pump through a cylinder containing the two thermometers. Different workers appear to hold very diverse opinions as to the reliability of the Assmann method.[2] As a control method Svensson used the Sonden hygrometer,[3] which measures the increase of volume produced on saturating the air. On this account, and also because of the different results of his two papers, Hazen severely criticises the whole investigation. We have not ourselves had an opportunity of using the Sonden instrument.

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[1] See also Rizzo, Nuovo Cimento, Oct. 1897, p. 241.

It is highly probable, therefore, that the apparent diminution of f in the observations discussed by Ekholm is due to a failure to comply with the conditions requisite for accurate use of the psychrometer, and this supposition is strongly borne out by the results of our observations, taken under more suitable conditions. Such a failure may occur occasionally under any circumstances, but, being of the nature of an accidental rather than a systematic error, it will be properly included among the casual variations of the single constant A. If, on the other hand, the diminution be due to hygroscopic action, it will be of a permanent nature, remaining more or less equal in all observations. Hence we have a means of directly testing the theory. If it be true, the observed value of t' will depend on the material used, and will always be too high. This will necessitate a correction to t' before inserting it in the ordinary psychrometrical tables, which are calculated for the standard case of $\eta = 1$. A short provisional table is given by Ekholm as an example of the corrections which would have to be applied. If, therefore, several wet-bulb thermometers covered with different materials be simultaneously observed, their readings should differ by amounts deducible from the values of η for each. As a rough indication of the extent of the differences to be expected at ordinary temperatures, consider the formula in the approximate form

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[1] Assmann, Meteor. Zeitschr., 1891, p. 15.

[2] Hazen, "Psychrometer Studien," Meteor. Zeitschr., 1896, p. 275. "Das Problem des Psychrometers," 1899, p. 261.

[3] Sonden, "Ein Neues Hygrometer," Meteor. Zeitschr., 1892, p. 81.

$$x = \eta f - \tfrac{1}{2}(t - t').$$

Using differential notation, suppose η to change by $d\eta$, and therefore t' by dt' and f by df, while x and t remain unaltered. Then

$$0 = f d\eta + \eta df + \tfrac{1}{2} dt'$$

or, putting $\eta = 1$ in the second term as a close approximation,

$$-f d\eta = df + \tfrac{1}{2} dt'$$

For linen and cotton, $d\eta$ is given by Ekholm as 0.056; near 0° C. we have $df = \frac{1}{3} dt'$ very nearly, whence $dt' = 0.31°$ neglecting sign. Similarly for linen and silk, $d\eta$ is given as 0.034; in this way we can draw up a table such as the following:—

		Linen-cotton.	Linen-silk.
t' about 0°	$df = \frac{1}{3} dt'$	$dt' = 0.31°$	0.19°
6°	$\frac{1}{2}$	.39°	.24°
12°	$\frac{2}{3}$	.50°	.31°
18°	1	.58°	.35°

Such differences are, of course, easily recognisable if they exist.

Thermometer-screen and Preliminary Work.

In carrying out this comparison it was thought advisable to restrict ourselves to natural atmospheric conditions, since they are the ones which are of practical importance. To examine the effect of different influences on the psychrometer, artificial regulation may be best, but the applicability of the results in practice must be tested under the conditions in which meteorological observations are usually taken. The ordinary types of thermometer-screen were not, however, suitable for the purpose, since it was desired not only to use several wet-bulb thermometers, but also to directly determine the humidity by another method. For these reasons a new screen was designed by one of us (E.F.J.L.), which is depicted in Plate XLVIII., looking respectively N.W. and S.W. towards the screen. It is large enough to allow the observer to be inside and yet well away from the instruments, and by means of a sliding bench it is always possible to keep to leeward of them, so that the effects of radiation from the person are as small as possible. Full protection from the sun's direct rays is afforded, and a double roof prevents heating from that direction, the air circulating freely between the roofs. The force of the wind is broken by louvring as shown, the ventilation being always ample. The dimensions of the screen internally are 65 in. (165 cms.) each way, the height running from 65 to 87½ in. (165 to 222 cms.). A trolley traverses the whole length, carrying a bench 48 in. (122 cms.) long, at a height of 50 in. (127 cms.) from the ground. The instruments are placed on this bench, which is adjusted to be out of the sun's rays and to windward of the observer. The outer roof is 12 in. (30.5 cms.) above the other.

By the kind permission of the University Council, and the generous provision by Professor Lyle of the necessary funds from the apparatus grant of the Natural Philosophy Department, the screen was set up in a suitable position in the grounds, the outlook being open on all sides, except for a wall distant 11 yards (10 metres) on the east. The prevailing winds are north and south, hence the screen was set facing south, the roof sloping downwards to the north.

Preliminary work was carried on by Mr. T. C Sutton, B.Sc., in 1909, with degree thermometers. Eleven thermometers of precisely similar size and shape were carefully compared and calibrated, of which seven were employed as wet-bulbs, and were covered respectively with silk, linen, wool (worsted), flannel, muslin, cotton-wool, and a mixed tussore fabric; the materials were first cleansed from grease, starch and other impurities by boiling in soda and distilled water. The whole eleven thermometers were suspended in a row above the bench, with the four dry-bulbs in the positions 1, 4, 8 and 11, the row being at right angles to the wind. Observations were only taken when the four dry-bulbs showed the same steady temperature, since then the intermediate wet-bulbs could be assumed to be under identical conditions. While the readings of the wet-bulbs were being taken, an observation of the dew-point was taken with a Regnault hygrometer. In all some sixty (60) observations were made, and Mr. Sutton reports that a striking feature is the consistency with which the various wet-bulbs rise and fall together with fluctuations in the humidity, etc. He also states: "In no case was there the slightest sign of any difference of temperature between the bulbs, so long as the water used was pure, and the terminal dry-bulb thermometers indicated the same temperature." These results showed that the difference, if any, was decidedly less than 0.1° C for dry temperatures ranging between 17° and 41.7° C. The next year, Mr. Sutton, being in England, made some more observations in a sheltered spot in the open at temperatures between —4° and 10°, at Twickenham, Middlesex. The differences in this case were certainly less than 0.2°, the limit of accuracy of the thermometers employed.

We were thus encouraged to proceed with the work in earnest this year. The values of the constant A obtained by Mr. Sutton showed a marked dependence on the velocity of the wind, suggesting some slight alterations in the construction of the screen which were carried out before beginning the new series of observations.

Apparatus and Procedure.

Three wet-bulb thermometers were used, all of Jena glass, graduated in tenths of a degree Centigrade, and with cylindrical bulbs. The materials were (1) silk, (2) linen, (3) cotton. Unfortunately the silk-covered one was broken after the work had been proceeding for some time, and before calibration had been completely carried out; it was replaced by another one, whose bulb was similar but shorter, no. 4 in the tables. The materials were cut from samples of fine Japanese silk, fine linen cambric, and book muslin of open texture; the pieces were thoroughly cleansed by boiling three times in succession, in caustic soda solution and in distilled water alternately. They were then sewn firmly round the bulbs, one thickness only, the rest hanging below.

The dry thermometer was also of Jena glass, similar to the others; it formed part of the condensation hygrometer used as a control. This was a Regnault double hygrometer, consisting of two precisely similar thimbles, one of which contains ether, and through both of which a steady current of air is drawn by an aspirator. Exception has sometimes been taken to the Regnault hygrometer on the ground that the silvered surfaces cannot be kept polished, being attacked by the gases of the air. This difficulty is avoided by using nickeled surfaces, which are found to keep a splendid polish until the nickel wears off. The curved surface is a slight disadvantage, but experience shows that it is of no consequence. The dew-point thermometer was of English glass, graduated in fifths of a degree Centigrade. The following table gives the dimensions and range of the several thermometers:—

	Bulb.		10 degree	Range.
	Length.	Diameter.	Length.	
1	4.5 cms.	0.52 cm.	4.40 cms.	−7° to 50°C.
2	4.0	.48	4.64	−4° ,,
3	4.0	.49	4.45	−5° ,,
4	2.9	.48	4.34	−8° ,,
Dry	3.6	.50	4.60	−5° ,,
Dew-pt.	3.7	.52	4.67	−12° to 46°

They were calibrated by direct comparison with a standard Negretti and Zambra, No. 65043, tested at Kew in March, 1888. The scale errors of this standard were all zero, except —0.1° at 100° C. The zero error, determined immediately before the calibration, was 0.2°. The scale errors of the other thermometers were in all cases small, those of the dew-point thermometer being practically zero throughout. Nos. 2 and 3 were in agreement over the greater part of the scale. All temperatures were recorded to the nearest twentieth of a degree; owing to the smallness of the spaces between the graduations and the unavoidable slight fluctuations during the course of an experiment, any nearer approximation gives only an apparent increase of accuracy. Moreover, tables of vapour-pressure at present differ from one another by amounts comparable even to the tenth of a degree. The table actually employed was that obtained by Broch by reduction of Regnault's observations, as given in the Physical Tables, Smithsonian Miscellaneous Collections, vol. 35.

Each observation involved the following procedure:—The three wet-bulb thermometers were suspended with their coatings dipping into water, and left to attain equilibrium with the surrounding air. Meanwhile the barometer and attached thermometer were read. Then the Regnault hygrometer was set up on the bench, which was adjusted to suit the wind; the wet-bulbs were thoroughly wetted by raising the water-vessel, which was then removed. The aspirator was started, and the wet-bulbs watched; after some fluctuation a minimum steady temperature was attained, which was noted. The dry bulb was immediately read, and the dew-point determined as rapidly as possible; since the temperature of the ether had been lowered while the wet-bulbs were being watched, the whole set of observations could usually be obtained in well under a minute. (The dry bulb is found to attain a steady temperature more quickly if it is dipped in the water for a few moments and then carefully dried before placing in the thimble; the current of air drawn past it ensures that it is always in contact with the outside air. At the beginning of the series an extra thermometer was hung outside with the wet-bulbs, and showed no divergence from that in the hygrometer). The direction and force of the wind were also noted—i.e., whether light, strong, etc. As far as possible, observations were taken twice a day, at about 11 a.m. and 3 p.m. Those here tabulated were taken between May 8 and July 4 inclusive.

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Observations and Results.

The complete list of corrected readings of the wet-bulbs is given in Table I., with the differences between them. The coatings are respectively (2) linen, (3) cotton, (4) silk. The first 52 observations of the silk-covered thermometer are not given, since they could not be properly corrected; the preliminary rough comparison which was carried out was sufficient, nevertheless, to show that they differed in no case from the others by more than 0.1° or 0.2°.

Table I.

No.	2	3	4	2—3	2—4
1	12.65	12.55		0.10	
2	12.35	12.25		.10	
3	11.25	11.25		0	
4	11.85	11.85		0	
5	12.95	12.95		0	
6	11.75	11.75		0	
7	11.85	11.85		0	
8	10.15	10.20		—.05	
9	9.65	9.70		—.05	
10	11.45	11.35		.10	
11	13.05	12.95		.10	
12	12.25	12.25		0	
13	14.95	15.00		—.05	
14	15.20	15.20		0	
15	14.30	14 30		0	
16	11.75	11.85		—.10	
17	11.35	11.35		0	
18	11.15	11.15		0	
19	11.15	11.05		.10	
20	12.95	12.95		0	
21	12.65	12.60		.05	
22	12.05	12.00		.05	
23	11.85	11.75		.10	
24	10.55	10.50		.05	
25	11.25	11.20		.05	
26	6.25	6.20		.05	
27	5.45	5.40		.05	

No.	2	3	4	2—3	2—4
28	8.85	8.85		0	
29	8.95	9.00		—.05	
30	9.45	9.50		—.05	
31	10.15	10.20		—.05	
32	8.75	8.90		—.15	
33	8.95	8.80		.15	
34	8.45	8.50		—.05	
35	8.15	8.10		.05	
36	5.50	5.45		.05	
37	5.65	5.55		.10	
38	7.85	7.80		.05	
39	8.15	8.10		.05	
40	7.75	7.80		—.05	
41	9.30	9.35		—.05	
42	5.20	5.15		.05	
43	5.85	5.90		—.05	
44	6.75	6.80		—.05	
45	7.35	7.40		—.05	
46	11.05	11.05		0	
47	11.15	11.10		.05	
48	10.05	10.10		—.05	
49	10.25	10.20		.05	
50	10.05	10.00		.05	
51	8.65	8.60		.05	
52	9.95	10.00		—.05	
53	8.85	8.90	8.85	—.05	0
54	9.15	9.20	9.15	—.05	0
55	10.15	10.20	10.05	—.05	.10
56	8.55	8.60	8.60	—.05	—.05
57	8.75	8.85	8.70	—.10	.05
58	7.55	7.50	7.40	.05	.15
59	6.45	6.60	6.45	—.15	0
60	6.55	6.60	6.65	—.05	—.10
61	9.45	9.40	9.40	.05	.05
62	8.85	8.80	8.75	.05	.10
63	7.75	7.60	7.60	.15	.15

Considering first nos. 2 and 3, linen and cotton, which differ most widely according to Ekholm's theory, this table shows that the differences are as often positive as negative—viz., out of 63 observations. 27 differences are positive, 23 are negative, and 13 are zero. They are distributed quite arbitrarily, without any reference to the values of t or t'. The largest individual difference is 0.15°, and this is twice positive and twice negative. The mean difference is 0.007°, which is certainly negligible, and the mean without regard to sign is only 0.05°, which is the observable limit.

For linen and silk there are only 11 observations, but the tendency to similar results is easily seen. The mean difference in this case is 0.04°, and the mean without regard to sign 0.07°. By comparison with the values to be expected from Ekholm's formula, it is evident that these are of the nature of accidental variations, and have no connection with any physical fact.

In Table II. are given the observations as a whole. The values under the heading t' are the means, where necessary, of the several wet-bulb readings; the pressure is given reduced to 0° C.

TABLE II.

No.	t	t'	Dew-point	B	Wind
1	14.75	12.60	11.05	763.8	Calm.
2	16.80	12.30	7.75	761.6	Calm.
3	15.85	11.25	6.45	760.2	Calm.
4	13.45	11.85	11.15	760.9	Gusty S.
5	15.65	12.95	11.75	759.2	Calm.
6	14.15	11.75	10.50	761.3	Strong S.E.
7	13.55	11.85	11.05	761.5	Light S.
8	13.55	10.20	7.55	766.2	Light S.
9	12.50	9.70	5.95	765.1	Light S.
10	14.05	11.40	9.10	767.3	Calm.
11	17.20	13.00	8.90	766.7	Calm.
12	14.65	12.25	10.50	766.6	Calm.
13	19.35	15.00	11.35	763.4	Light N.
14	18.10	15.20	12.85	758.6	N. breeze.
15	17.40	14.30	11.25	757.5	N. breeze.
16	16.70	11.80	8.10	756.9	N. breeze.
17	14.20	11.35	9.00	758.7	Strong N.
18	11.90	11.15	10.95	761.5	Fresh S.

No.	t	t'	Dew-point	B	Wind
19	12.40	11.10	10.50	759.8	S. breeze.
20	14.25	12.95	11.45	760.5	Calm.
21	14.45	12.60	11.30	761.0	Light S.
22	15.35	12.00	10.00	760.9	Fresh N.
23	14.35	11.80	9.10	759.1	Strong N.
24	12.80	10.50	8.60	756.0	Strong N.
25	13.65	11.20	9.15	754.0	Strong N.
26	7.35	6.20	4.95	761.4	Strong S.
27	8.55	5.40	1.85	760.4	Light S.
28	11.10	8.85	5.90	757.6	S.W. breeze.
29	11.80	9.00	5.85	757.4	Strong S.W.
30	11.20	9.50	7.75	761.8	Light S.
31	11.10	10.20	8.55	761.4	Calm.
32	11.80	8.80	4.60	766.4	Calm.
33	12.95	8.90	4.55	764.6	N. breeze.
34	11.80	8.50	5.75	763.9	N. breeze.
35	11.20	8.10	5.05	762.1	N. breeze.
36	7.65	5.50	3.30	757.5	Calm.
37	8.95	5.60	2.30	756.6	Light S.W.
38	10.25	7.80	2.95	762.2	Light N.W.
39	11.60	8.10	3.10	760.3	Light N.W.
40	9.65	7.80	5.95	754.3	Strong N.W.
41	11.20	9.30	7.15	750.8	Strong N.W.
42	8.45	5.20	0.80	747.0	Strong N.W.
43	9.25	5.90	1.00	746.8	Strong N.W.
44	9.45	6.80	4.15	754.3	S.W. breeze.
45	9.75	7.40	5.10	756.1	Light S.W.
46	12.00	11.05	10.10	766.1	Light S.W.
47	12.10	11.10	10.20	765.9	Light S.
48	10.90	10.10	8.95	770.4	Calm.
49	12.50	10.20	7.50	769.5	Calm.
50	12.40	10.00	7.25	767.4	Light N.W.
51	10.90	8.60	6.90	766.2	Light N.
52	12.00	10.00	7.95	763.3	Light N.
53	12.10	8.85	6.10	769.1	N. breeze.
54	12.35	9.15	5.95	768.2	Light N.
55	12.80	10.15	7.35	770.1	Calm.
56	10.85	8.60	7.30	767.7	Light N.

Not	t	t'	Dew-point	B	Wind
57	11.30	8.75	6.35	764.0	N. breeze.
58	10.85	7.50	3.65	764.1	Variable light.
59	10.95	6.50	1.20	763.7	Light S.W.
60	9.35	6.60	2.55	768.4	Light N.
61	9.75	9.40	9.00	769.0	Calm.
62	10.65	8.80	6.75	768.7	Calm.
63	9.65	7.65	3.95	774.1	Calm.

Applying the formula,

$$x = f - \mathrm{AB}\,(t - t'),$$

the vapour-pressures being taken from Broch's tables, the values of A are calculated. The mean is 0.0007228, with a probable error of 0.0000175, or, approximately,

$$\mathrm{A} = (72 \pm 2) \times 10^{-5}$$

The individual values of A vary rather widely, but all have been included, since the comparison of the wet-bulbs is not affected by other errors, such as a lack of precision in the indication of the Regnault hygrometer. Some of the largest discrepancies have been traced with great probability to an error of reading amounting to half a degree. The tendency to such a mistake was always present, owing to the method of marking of the thermometers, and its occurrence was actually detected in later observations, when it was watched for. It was not thought advisable, however, to make any tentative corrections of this nature. The outstanding errors being few, and both positive and negative, will not affect the mean value by much. It is somewhat high, compared with other observers' results, but this may be partly due to the fact that the values of $t - t'$ are all small, none being above 5°, although the dry temperatures range from 7.35° to 19.35°. As is seen in the next table, the values of the humidity are correspondingly fairly high throughout, being never less than 50 per cent.

With this mean value of A the corresponding values of x were calculated, and are included in Table III. under $\bar{x}$. The humidities calculated from x and x are also tabulated as r and r, with the difference, or errors, $\Delta x = x - \bar{x}$ and $\Delta r = r - \dot{r}$.

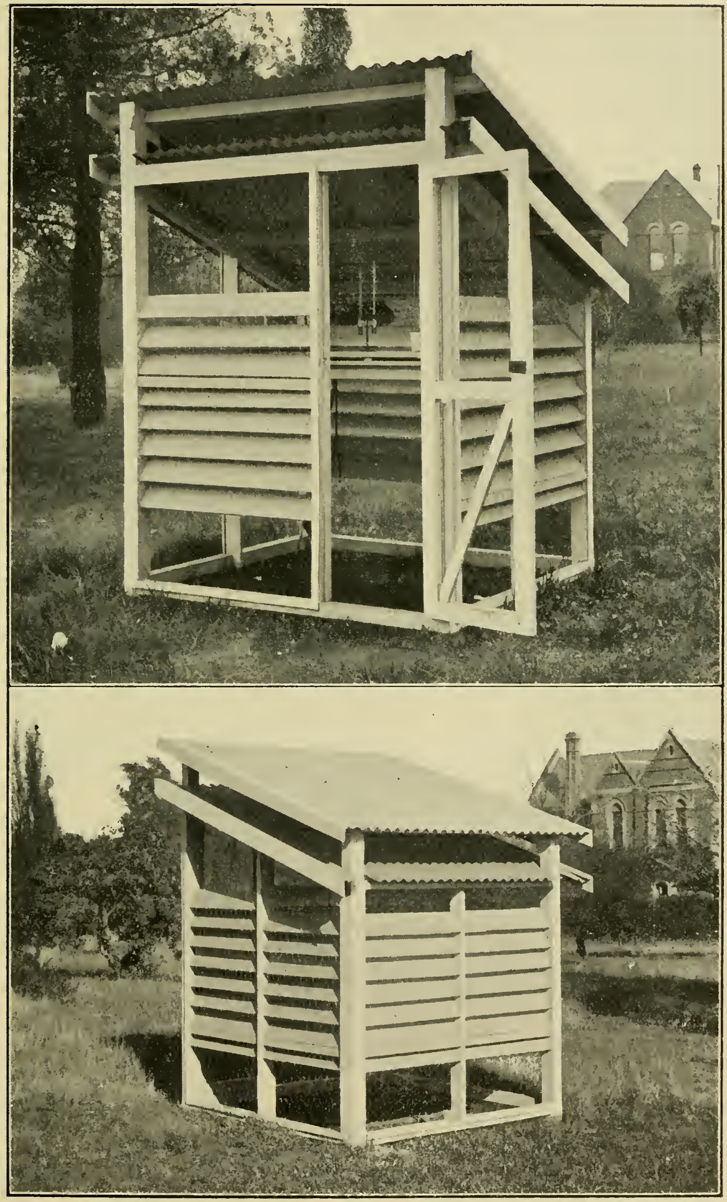
TABLE III.

No.	x	x	Δx	r	r	Δr
1	9.80	9.66	.14	78.59	77.47	1.12
2	7.86	8.16	—.30	55.31	57.42	—2.11
3	7.19	7.40	—.21	53.74	55.31	—1.57
4	9.87	9.45	.42	86.05	82.39	3.66
5	10.27	9.62	.65	77.75	72.83	4.92
6	9.45	8.95	.50	78.75	74.58	4.17
7	9.80	9.39	.41	84.92	81.37	3.55
8	7.75	7.40	.35	67.16	64.12	3.04
9	6.95	7.41	—.46	64.47	68.74	—4.27
10	8.61	8.56	.05	72.23	71.81	0.42
11	8.49	8.81	—.32	58.23	60.43	—2.20
12	9.45	9.28	.17	76.27	74.90	1.37
13	10.00	10.27	—.27	59.95	61.57	—1.62
14	11.03	11.25	—.22	71.49	72.91	—1.42
15	9.93	10.42	—.49	67.28	70.59	—3.31
16	8.05	7.62	.43	56.97	53.93	3.04
17	8.55	8.44	.11	71.01	70.10	0.91
18	9.74	9.46	.28	93.93	91.22	2.71
19	9.45	9.13	.32	88.23	85.25	2.98
20	10.06	10.39	—.33	83.28	86.01	—2.73
21	9.97	9.83	.14	81.52	80.37	1.15
22	9.14	8.59	.55	70.52	66.28	4.24
23	8.61	8.90	—.29	70.81	73.19	—2.38
24	8.32	8.19	.13	75.70	74.52	1.18
25	8.63	8.56	.07	74.27	73.66	0.61
26	6.49	6.44	.05	84.95	84.29	0.66
27	5.22	4.96	.26	62.97	59.83	3.14
28	6.93	7.23	—.30	70.43	73.48	—3.05
29	6.90	7.02	—.12	66.99	68.16	—1.17
30	7.85	7.90	—.05	79.29	79.80	—0.51
31	8,29	8.76	—.47	84.25	89.02	—4.77
32	6.33	6.77	—.44	61.46	65.73	—4.27
33	6.31	6.25	.06	56.85	56.31	0.54
34	6.86	6.45	.41	66.60	62.62	3.98
35	6.53	6.37	.16	65.96	64.31	1.65
36	5.78	5.55	.23	74.01	71.06	2.95
37	5.39	4.95	.44	63.26	58.10	5.16

No.	x	x	Δx	r	$\bar{r}$	Δr
38	5.64	6.53	—.89	60.71	70.29	—9.58
39	5.70	6.13	—.43	56.10	60.34	—4.24
40	6.95	6.87	.08	77.83	76.93	0.90
41	7.55	7.69	—.14	76.26	77.68	—1.42
42	4.84	4.84	.00	58.74	58.74	0.00
43	4.91	5.11	—.20	56.50	58.80	—2.30
44	6.13	5.92	.21	69.58	67.20	2.38
45	6.56	6.39	.17	72.97	71.08	1.89
46	9.20	9.27	—.07	88.21	88.88	—0.67
47	9.26	9.29	—.03	88.19	88.48	—0.29
48	8.52	8.75	—.23	87.84	90.21	—2.37
49	7.73	7.98	—.25	71.71	74.03	—2.32
50	7.59	7.81	—.22	70.87	72.92	—2.05
51	7.42	7.05	.37	76.42	72.61	3.81
52	7.96	8.04	—.08	76.32	77.09	—0.77
53	7.02	6.65	.37	66.86	63.33	3.53
54	6.95	6.85	.10	65.14	64.20	0.94
55	7.65	7.75	—.10	69.71	70.52	—0.81
56	7.62	7.07	.55	78.80	73.11	5.69
57	7.15	6.99	.16	71.72	70-11	1.61
58	5.92	5.88	.04	61.22	60.81	0.41
59	4.98	4.76	.22	51.13	48.87	2.26
60	5.48	5.73	—.25	65.28	68.26	—2.98
61	8.55	8.59	—.04	95.11	95.55	—0.44
62	7.34	7.40	—.06	76.94	77.57	—0.63
63	6.07	6.69	—.62	67.97	74.92	—6.95

In spite of the large variations of A from the mean, the errors of x and r are for the most part small. The probable error of a single observation of x is 0.22 mm. and of r 2.05 per cent. A few large errors of course appear. but as stated before, they are most likely due to errors of reading.

It remains to apply Ekholm's two-constant formula to the same observations. and see whether any improvement is effected in the agreement between observation and calculation. The values of η and A, as determined by least squares from the 63 observations, are 0.9974 and 0.0007062 respectively. That is, η is indistinguishable from unity to the order of accuracy which can be attained in such observations, and A is within



the limits of the probable range set by the other formula. The probable errors of these values are 0.0077 and 0.0000341. It is needless to calculate values of x and r from this formula; they could not show any perceptible difference from the others.

Conclusions.

Our observations show clearly that the reading of a wet-bulb thermometer is not dependent in any way on the nature of the material with which the bulb is covered, provided at any rate that the material be one of those generally recognised as suitable. (The only other work which deals with this question at all, so far as we know, is that of Edelmann[1], who examined only various cotton-stuffs, and under the very special conditions of perfectly dried air. The different materials were not compared directly, but the mean values of the constant obtained by observations with each differed slightly; since, however, the difference was not as much as the variations in any one set no definite conclusion can be drawn from such experiments). This proves that no hygroscopic action occurs at the temperatures and under the conditions of these experiments, and they are the ones of largest practical importance at present.

Moreover, the result shows that in the great majority of cases there is no such diminution of $/$ as has been shown to be possible, apart from hygroscopic action. The variations of A are purely accidental, and not systematic. The conclusion is abundantly justified that under proper working conditions the constant η is unity, as in the ordinary theory, and this independently of the kind of material used to coat the wet-bulb thermometer. Conversely we may gather that the ordinary theory of the psychrometer is essentially correct, and that the conditions under which this work was done are eminently suitable to the proper use of it as a meteorological instrument.

Further observations on the same lines are being carried on, and we hope to publish next year a supplement to this paper containing the results of a more extended experience. With the advent of warmer weather. observations under conditions of less humidity may be expected, and it is possible that the value of A will then be found to be somewhat lessened. The results so far have shown no systematic dependence of A on wind-velocity or direction, though there appears to be a tendency for it to decrease as the velocity rises and as the wind changes from north to south. In calm air the values are certainly larger than when the air is moving. This is in accordance with the results of other observers and with the Stefan-Maxwell theory. The mean value of A for calm air is 0.0008370, for moving air 0.0006806; the latter number agrees nearly with those obtained by others using artificial ventilation.

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[1] Edelmann, Meteor. Zeitschr., 1896, p. 325.

In conclusion we desire to record our thanks to Professor Lyle for the kindly interest which he has shown, and for the loan of the thermometers, which has enabled the work to be done in a satisfactory manner.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XVII.—*Some New Australian Cicadidae.*

By HOWARD ASHTON.

(With Plates XLIX-LI.)

[Read 14th September, 1911.]

For most of the material from which the following new species of *Cicadidae* are described, I have to thank Mr. F. P. Dodd (Queensland) and Mr. H. Elgner, of the same State. Amongst them it will be noticed is a new species of *Cyclochila* from Queensland, and also a species of *Prasia*, a genus so far unrecorded in Australia, though common in New Guinea. I have had some difficulty in deciding upon the generic determination of *Psaltoda pulchra*, as it has strong affinities with *Thopha* in the structure of the head and the proportions of the tegmina and wings. The abdomen, however, is unadorned with the sacs which hide the tympana in the division *Thopharia*, so I have placed the species tentatively in the genus *Psaltoda*. The types of all these species are in my collection.

Sub-family Cicadinae.

Division *Cyclochilaria.*

Cyclochila laticosta, sp. nov.

Similar in colour and size to *C. australasiae*, Donov, from which it differs chiefly in the immense breadth of the tegminal costal membrane, which is as wide as the radial area. The front is far less prominent than in Donovan's species, the membranous margins of the tegmina and wings very much narrower, the opercula broader, not sinuate on the exterior margins and more obtusely rounded posteriorly.

Long. (excluding tegmina) — ♂ 44 ♀ 41 mm.; exp. teg. ♂ 125 ♀ 122 mm.

Hab.—Queensland (Evelyn Scrub), Mr. F. P. Dodd.

Psaltoda pulchra, sp. nov.

♂ Head, pro-and mesothorax olivaceous-green. Head with a broad black fascia between eyes, and including region of ocelli, another black fascia across base of front. Pronotum with sulci, anterior border of posterior margin, and spot before centre of same, black. Mesonotum with two central anterior ochraceous obconical spots margined with black, on each side a small marginal spot and a long sublateral fascia (extending to anterior angles of cruciform elevation), a median slender fascia, and two black spots within anterior angles of cruciform elevation, black. Cruciform elevation chocolate brown. Abdomen with lateral areas and posterior segmental margins covered with silvery hairs, the first two segments and tympanal coverings greenish, a broad black fascia running between these two segments and behind the tympanal covers, and a rounded spot on each lateral margin of second segment, black. Remaining segments chocolate-brown, broadly margined with black posteriorly. Tegmina hyaline, talc-like, venation chocolate brown, costal membrane and longitudinal veins and basal vein to lower ulnar area green, veins at bases of first and second apical areas, apices of longitudinal veins to all the apical areas, exterior membranous margin and tips of tegmina infuscated. Wings hyaline, talc-like, venation chocolate-brown, abdominal area tinged with deep, rich orange, exterior membranous margin darkly infuscate. Head, thorax, legs and opercula beneath greenish. A broad fascia from face to eyes, central sulcus and transverse striae to face, soxae beneath, stripes to femora and bases of tarsi, median line and tip of rostrum, black. Abdomen beneath transparent ochraceous, posterior margin of first segment broadly black. Rostrum reaching apices of posterior coxae, opercula overlapping internally.

Long.—(excl. teg.) 49 mm.; exp. teg. 140 mm.

Hab.—Queensland (Evelyn Scrub).

Psaltoda fumipennis, sp. nov.

♂ Head, pronotum and mesonotum olivaceous-green. Head with eyes black, front and broad fascia across vertex, black. Pronotum with anterior margin, sulci, anterior border of posterior margin and spot on anterior angles of lateral margins, black. Mesonotum with two anterior central inwardly curved fasciae, between which is a fine longitudinal median fascia, and outside of which, on each side, is a small obconical anterior spot, and a series of four small spots along the anterior concavity of cruciform elevation, black. Abdomen brownish-ochraceous, anterior and posterior margin of first segment finely black, posterior margins of remaining segments fuscous. Tegmina and wings hyaline, talc-like, costa and venation fuscous, veins at bases of second and third tegminal apical areas broadly infuscate, tips of tegmina and wings strongly tinged with fuscous. Head beneath, sternum and legs, pale green, narrow fasciae between base of face and eyes black, rostrum, tibiae and tarsi brownish, opercula ochraceous, abdomen beneath luteous, translucent. Rostrum barely reaches posterior coxae. Head, including eyes, a little broader than base of mesonotum, front broad, not prominent. Abdomen above considerably longer than space between apex of front and base of cruciform elevation. Opercula obtusely rounded posteriorly, overlapping internally.

Long.—(excl. teg.) 32 mm. ; exp. teg., 86 mm.

Hab.—Port Darwin (?). Mr. F. P. Dodd.

This species may be easily recognised by fuscous tips to tegmina and wings.

Division *Cicadaria.*

Macrotristria doddi, sp. nov.

♂ Head ochraceous, area of ocelli, with short fasciae reaching half-way to eyes, black. Pronotum light castaneous, two black spots before centre of posterior margin ; central fascia, broadened anteriorly, and posterior margin, ochraceous. Mesonotum ochraceous, two longitudinal central fasciae (which meet a lateral fascia in front of cruciform elevation), black, on each side a large anterior marginal black spot, and a broad suffusion about it castaneous. Cruciform elevation fuscous. Abdomen piceous, thickly greyishly pilose. Tegmina and wings hyaline, venation reddish fuscous, veins at bases of second, third, fourth, fifth and seventh tegminal apical areas infuscated, and a series of fuscous submarginal spots on apices of longitudinal veins to all apical areas. Basal membranes of tegmina and wings pale green. Head beneath ochraceous, face castaneous, broad black fascia from face to eyes. Sternum and opercula ochraceous, legs pale castaneous, tarsi darker, rostrum pale castaneous, tip piceous. Abdomen beneath ochraceous, lateral margins, a narrow central longitudinal fascia, greater portion of disc of apical segment and anal appendage shining piceous. Rostrum just passing apices of posterior coxae, opercula reniform, broadly posteriorly rounded, and overlapping internally.

Long.—(excl. teg.), 33 mm.; exp., 94 mm.

Hab.—Port Darwin (Mr. F. P. Dodd.)

Sub-family TIBICININAE.

Division *Chlorocystaria.*

Owra, gen. nov.

♀ Head, including eyes, broader than base of mesonotum, front broader than half the space between eyes, not prominent, ocelli equidistant from eyes and from one another. Pronotum rather longer than head, lateral angles almost as broad as eyes. Mesonotum a little shorter than pronotum and head together, abdomen about as long as thorax and head together. Rostrum reaching bases of lined coxae. Tegmina and wings hyaline. Tegmina with no membranous margin, ulnar areas somewhat reticulate, nine apical areas. Wings with five apical areas, and narrow membranous margin.

Type —*O. insignis.*

Owra insignis, sp. nov.

♀ Head, pro- and mesonotum green, eyes piceous, abdomen ochraceous. Tegmina hyaline, costal membrane rufous, broadened at apex, post-costal area transparent and somewhat cell-like, remaining venation of tegmina and wings piceous, basal membranes of tegmina rufous. Head beneath green, sternum anteriorly green, shading posteriorly to ochraceous, abdomen ochraceous, legs ochraceous, tarsi reddish.

Long.—(excl. teg.), 12 mm.; exp. teg., 37 mm.
Hab.—Queensland. (Mr. F. P. Dodd.)

Thaumastopsaltria glauca, sp. nov.

♂ Body light greyish-green, eyes brown. Tegmina hyaline with pale green tinge and green neuration. Apical cells very long, 13 in number. Wings similar in colour, with 7 apical areas, very long. Body below inclining to yellowish. Rostrum just passes intermediate coxae; opercula obsolete; abdomen in ♂ moderately inflated, and laterally depressed more than twice as long as head and thorax together.

Long.—(excl. teg.), ♂ 26, ♀ 20 min., exp. teg., ♂ ♀ 55 min.
Hab.—North Queensland (Cape York). Mr. H. Elgner.

Division *Melampsaltraria.*

Melampsalta brevis, sp. nov.

♂ Head above black, with greenish yellow spot behind ocelli and yellow central longitudinal stripe to front. Pronotum light castaneous, anterior and posterior borders and central longitudinal fascia (enclosed by two black stripes ampliated anteriorly and posteriorly), ochraceous, lateral margins inwardly black. Mesonotum centrally ochraceous, laterally castaneous, the ochraceous portion containing two central anteriorly contiguous obconical spots, joined posteriorly to two triangulate spots before cruciform elevation, and disc of cruciform elevation, black. The castaneous lateral portions containing each a black fascia outwardly concave, and a sublateral anterior marginal spot, black. Abdomen with basal and second segment stramineous, a spot behind cruciform elevation, and short transverse fascia on posterior margin, basal segment black, remaining segments castaneous with posterior margins black. Tegmina and wings hyaline, basal membranes red, venation fuscous, costal area ochraceous. Head beneath black, face fuscous, lateral striae black, margins of face ochraceous. Sternum, legs and opercula greyish ochraceous, legs streaked to piceous. Abdomen ochraceous, obsolete central fuscous longitudinal fasciae. Rostrum reaching posterior coxae. Opercula rectangular, meeting internally, a piceous spot on abdominal segment above outer angle. Head (excluding eyes) twice as broad as long, front not prominent, including eyes broader than base of mesonotum. Pronotum as long as mesonotum (excluding cruciform elevation). Abdomen very short, equal in length to pro- and mesonotum together, first two segments equal in length to all of the rest.

Long.—(excl. teg.), 12 mm.; exp. teg., 46 mm.

Hab.—North Queensland, Cape York. (Mr. H. Elgner.)

Remarkable for the extreme shortness of the abdomen.

Melampsalta viridis, sp. nov.

♂ Body above green, beneath green, inclining to yellow, eyes pale brownish. Tegmina and wings hyaline, talc-like, venation on basal third green, thence becoming fuscous. The only markings are two small black spots, one on each side of the anal appendage. Pronotum and head deeply centrally sulcate, rostrum reaching intermediate coxae, opercula lunate, much narrower than abdominal orifices, curved inwardly.

Long.—(excl. teg.), 13 mm.; exp. teg., 31 mm.

Hab.—Queensland (?) Mr. F. P. Dodd.

Allied to *M. sulcata*, Dist., with the same narrow crescent-shaped opercula, but differing in the shorter tegmina, as well as in colour. *M. froggatti*, Dist., and *M. capistrata*, Ashton, have similar curiously shaped opercula.

Melampsalta crucifera, sp. nov.

♀ Body above ochraceous. Head with oblique black fasciae to front, joining with fasciae on vertex towards eyes, at inner angles of which the fasciae turn inwardly, the whole series forming a square interrupted by the two posterior ocelli. From these two ocelli run two slender fasciae forward through the third ocellus, and continuing on to near base of front, forming a cross of which the anterior ocellus is the centre. Pronotum with two broken central longitudinal fasciae and irregular markings to incisures, anterior border of posterior margin brokenly edged with black. Mesonotum with two central anterior contiguous black obconical spots, on each side a larger obconical spot, obsolete, two small spots before anterior angles of cruciform elevation, black. Tegmina hyaline, talc-like, venation basally reddish ochraceous, apically fuscous, wings similar. Abdomen with a central black longitudinal fascia along dorsal ridge, and a fuscous fascia along each lateral margin, a black stripe on each side of anal segment and ovipositor, which is very long, black. Head beneath, with four black spots, two on face and one on each side near base of antennae. Anterior coxae and femora spotted with black, central longitudinal abdominal fascia also black.

Long.—(excl. teg. and incl. ovipositor), 18 mm. ; exp. teg., 40 mm.

Hab.—Queensland (?). Mr. F. P. Dodd.

Allied to *M. binotata*, God. and Frogg., but differing in the longer and uncoloured tegmina and the distinct yellow colouration.

Pauropsalta elgneri, sp. nov.

♂ Head greyish yellow, region of ocelli black, pilose. Pronotum very light ferruginous, margins and central longitudinal fascia pale greenish ochraceous. Spot on centre of posterior margin and incisures brokenly black. Mesonotum greyish ochraceous, two central anterior obconical spots black, two outer longer fasciae light castaneous, with bases and tips black. Tegmina and wings hyaline, talc-like, venation reddish at base, and fuscous towards apex, anal apex of wings infuscated. Abdomen reddish-yellow, greyishly pilose, base of anal appendage broadly black. Body beneath ochraceous, head and sternum thickly greyishly pilose, face piceous, anterior coxae and femora streaked with fuscous. Opercula narrow, directed strongly inwards, apices sub-acutely convex.

Long.—(excl. teg.), 19 mm. ; exp. teg., 53 mm.

Hab.—Queensland, Cape York. (Mr. H. Elgner.)

This species is somewhat allied to *P. melanopygia*, Germ. It differs in the longer and narrower tegmina, the narrower opercula and the laterally depressed abdomen.

Pauropsalta subolivacea, sp. nov.

♂ Head black, pilose, eyes fuscous. Pronotum testaceous, a central black fascia dilated anteriorly and posteriorly (enclosing a pale central stripe). Some spots about the incisures black, posterior margin very narrow, ochraceous. Mesonotum testaceous, two central obconical spots on anterior margin cruciform elevation sordid pale fuscous. Abdomen testaceous, pilose, segments with basal margins black, apex of first and second segment narrowly ochraceous, lateral margins suffused with greenish olive. Body beneath yellow, suffused on legs, opercula and lateral margins of abdomen with greenish olive. Tegmina and wings hyaline, costa dull ochraceous margined with black, interior venation black, apical paler. Head, excluding eyes, as broad as long, front much produced, vertical margins continuous. Pronotum as wide as head, and as long. Mesonotum as broad as pronotum, and, from base of cruciform elevation, as long as pronotoum and head together. Abdomen long, slender, tapering, as long as head and thorax.

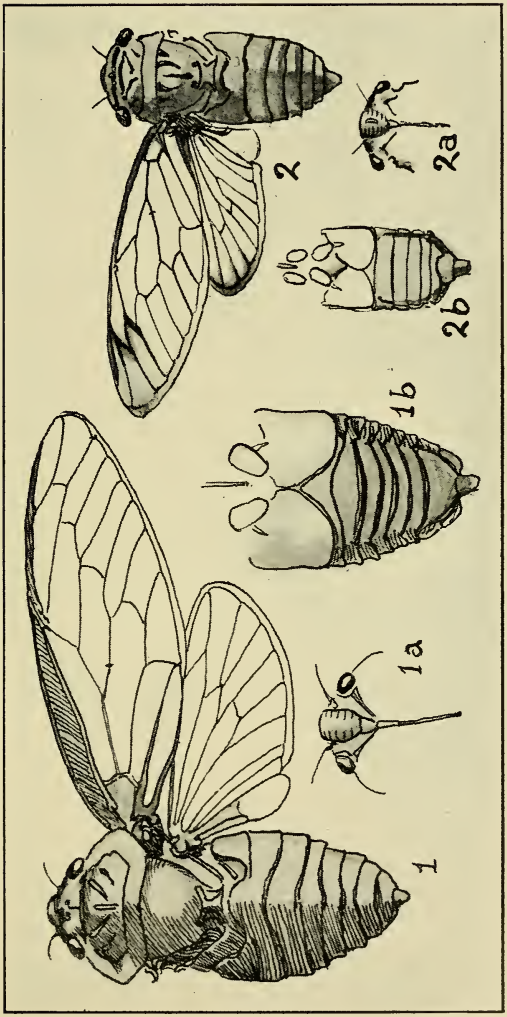
Long.—(excl. teg.), 14 mm.; exp. teg., 38 mm.

Hab.—New South Wales.

Division *Hemidictyaria.*

Prasia vitticollis, sp. nov.

♀ Body pale fuscous yellow. Eyes brown, front and anterior margins of vortex of head tinged with dull green, central sulcus from between ocelli to base of pronotum dull piceous, two spots before cruciform elevation and central longitudinal line to same piceous, obsolete piceous suffusions to base of anal segment, and ovipositor also piceous. Body beneath pale fuscous yellow, face tinged with piceous anteriorly, sternal margins tinged with dull green, apices and bases of tibiae and tarsi and apex of rostrum spotted with piceous. Tegmina opaque, venation ochraceous to fuscous, closely spotted with darker colour. Wings somewhat milky, venation very pale fuscous. Head strongly produced, longer than breadth between eyes. Pronotum more than twice as broad at base as anteriorly,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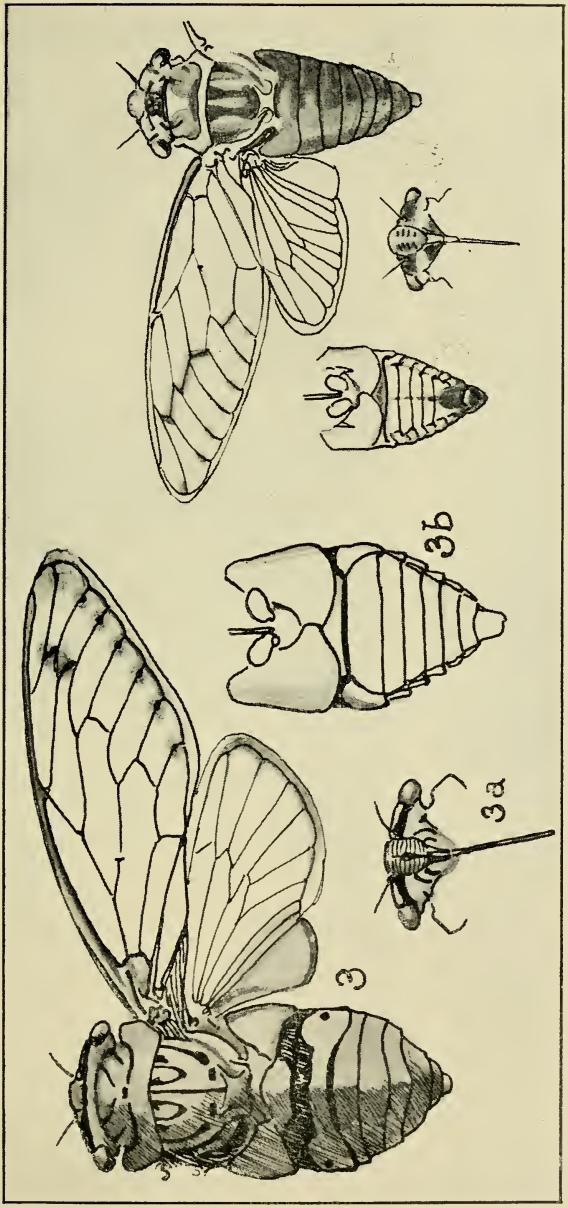
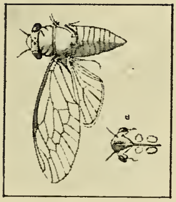
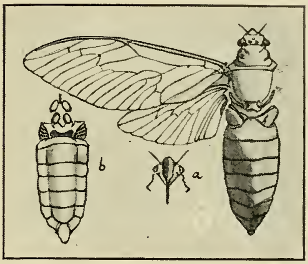
Proc. R.S. Victoria, 1911. Plate L.



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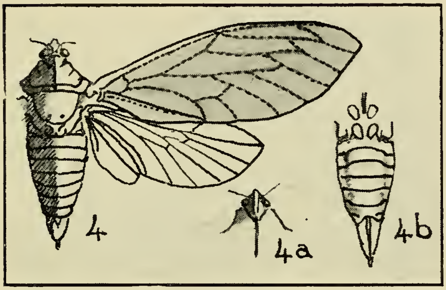
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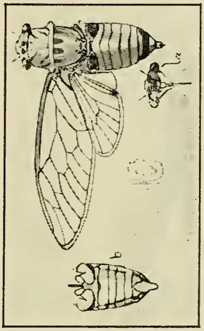

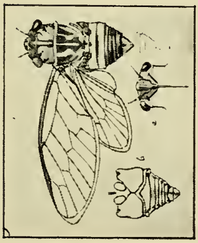

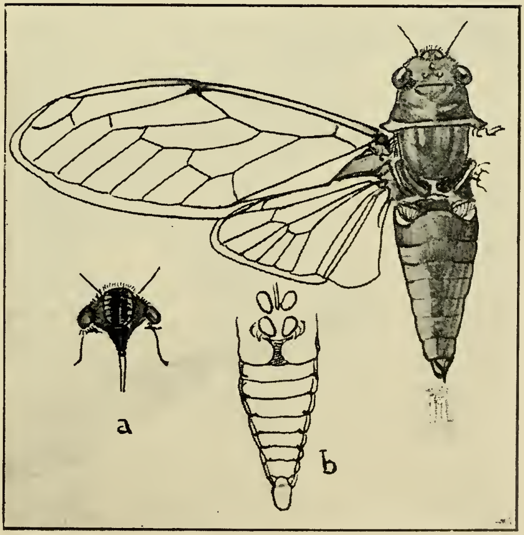
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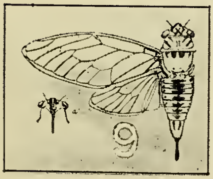
a

lateral margins posteriorly ampliated and rounded. Mesonotum (including cruciform elevation) equal in length to head and pronotum together, abdomen longer than space between base of cruciform elevation and apex of front. Face very prominent and very thin, not at all globose, narrowly centrally sulcate and faintly laterally striate. rostrum reaching intermediate coxae, two very long spines, besides posterior coxae.

Long.—(excl. teg.), 28 mm.; exp. teg., 88 mm.

Hab.—Queensland (?). Mr. F. P. Dodd.

EXPLANATION OF PLATES.

Plate XLIX.

Fig. 1, a, b.—Cyclochila laticosta.
2, a, b.—Psaltoda fumipennis.

Plate L.

3, a, b.—Psaltoda pulchra.
5, a, b.—Macrotristria doddi.

Plate LI.

4, a, b.—Prasia vitticollis.
6, a.—Owra insignis.
7, a, b.—Melampsalta brevis.
8, a, b.—Thaumastopsaltria glauca.
9, a.—Melampsalta crucifera.
10, a, b.—Pauropsalta elgneri.
11, a, b.—Pauropsalta subolivacea × $\frac{3}{2}$.

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Art. XVIII.—*Osmotic Equilibration in the Living Body.*

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(Communicated by the Honorary Secretary).

[Read 12th October, 1911].

The primitive form of life from which all present existent forms of animal life are derived was, according to the Darwinian theory, a unicellular organism, analogous to the *Amoeba*, which, undoubtedly, lived in the ocean. From this form were evolved the simple coelenterates, and ultimately animals appeared which contained in their organisation a closed cavity which contained a fluid undoubtedly derived from the environment, the ocean. This closed cavity and its contained fluid were ultimately destined to become the circulatory system and the circulating fluid (blood) of the higher animals.

When these primitive animals left the sea and took to an estuarine life as a preliminary to living in the mud and, ultimately, on dry land, they took with them, contained in this body cavity, a fluid which had the same chemical composition as the ocean, their original home.

In the future evolution of this type of terrestrial animal, it is legitimate to postulate that the composition of this fluid remained about the same, and thus the animal, its cells attuned to a fluid of this composition, and by its terrestrial life removed from any chance of being exposed to any alterations in the composition or concentration of this circulating fluid, was given every opportunity of ascending in the scale of evolution.

We have here the first example of standardisation in the body, one of the principal stepping-stones to the proper and efficient evolution of the individual and race, a process well exemplified in the high degree of standardisation met with in the higher mammals, not only of the osmotic pressure of the blood, but also the chemical composition, salt ratios, surface tension, and viscosity of the blood, as well as standardisation of body temperature, rate of heart beat, and rate of respiration; the higher the animal the greater is the degree of standardisation of its various functions.

Those animals, however, which had remained in the sea, or the early descendants of the primitive terrestrial animal which had migrated back to this ocean which Macallum (6) places in precambrian times must, since those times, have had a constant fight against the increasing concentration of the ocean. On the other hand, those primitive creatures which had betaken themselves to the fresh water must have had a fight against the tendency to dilution of their body fluids.

With what mechanisms, then, is the animal organism endowed which enable it to oppose environmental influences affecting the osmotic pressure of its blood?

We know that one of the chief functions of the kidneys is to maintain the osmotic pressure of the blood constant, and, since in the mammal (for we know more of mammals and are better able to study them) there is a constant drain of water from the blood to supply the sweat and saliva, both very watery fluids (all other secretions being more or less isotonic with blood), the kidney is normally called upon to secrete a fluid whose osmotic pressure is generally very much above that of the blood. In this connection the results of Sommerfeld and Roder (13) are of interest. The osmotic pressure of the urine of a suckling fed on different milk diets was determined, and it was found that on a diet of full cow's milk the urine had a Δ of 0.736°C, and on its mother's milk the urine of the suckling gave a Δ of 0.746°C. But there is another means at the disposal of the organism, and that is by allowing entry into the alimentary canal of foods whose osmotic pressure is not above that of the blood, or in the case of sea animals (teleosts upwards), where this is not possible, either the non-absorption of the extra saline constituents of the sea-water, or if the absorption of these substances does take place, their elimination by the kidney. Bottazzi (1) has shown in the case of the marine teleosts that the latter process takes place, but whether marine mammals have adopted this practice, or whether they simply do not absorb the excess of salt (and thus of necessity do work against osmotic pressure), has not been determined, but the fact that the Δ of the urine of seals recorded by Portier gives values of 0.73 to 3.5 seems to point to the fact that salts are absorbed and excreted by the kidney, the urine probably having a low Δ between meals and a high Δ during digestion, as suggested by Bottazzi (1). But in regard to land mammals in general and man in particular, my own observations on the osmotic pressure of liquid foods throw some light on the subject.

It is generally admitted that one of the functions of the stomach is the establishment of osmotic equilibrium between the fluid food swallowed and the blood (3). This it does by adding salts, etc., to hypotonic fluids, and by diluting the hypertonic. In the latter function the action of the stomach is aided by the salivary glands, which pour out a copious secretion of saliva. In one experiment cited in the appendix, 72 c.c. of saliva were poured out in 15 minutes during the process of chewing about 12 grms. of barley-sugar.

This function is no doubt protective, for the deleterious effects of exposing tissue cells to the action of hypertonic or hypotonic fluids are well known. The swelling up of, and interference with sensation in, and the function of the skin after prolonged immersion in water, and on the other hand the "roughness" produced when a piece of confectionery is retained for a few minutes between the teeth and cheek, are common examples.

Of the foodstuffs ordinarily admitted to the stomach, the great majority are in solid or gelatinous or colloidal form, and to such substances the considerations of osmotic pressure cannot apply. The actual fluid foods admitted to the stomach of man are milk, the ordinary beverages, fruit juices and beef teas, meat extracts and soups, while in the case of the lower animals in the natural state, the list is very much shortened, since the ingestion of prepared foods is solely confined to man and the domestic animals. In tea, coffee and cocoa there is usually a sugar addition, which varies with the personal taste, but the Δ given by the contents of a cup of tea, as prepared for an ordinary individual, was found to be about 0.46°C. The Δ of milk has been determined by many observers, and is the same as the blood, 0.57-0.59. Of all the fluid foods admitted to the stomach of man, alcoholic beverages and fruit juices alone are hypertonic. In fact most of the fluid foods admitted to the stomach are hypotonic, thus containing a water excess which the organism readily avails itself of for purposes of "flushing out" the system, and which also allows of the addition of hydrochloric acid in the stomach. Moreover, it may be safely stated that in no case is a fluid admitted in which the hypertonicity is due to the mineral ingredients alone, except under protest. The sense of taste stands at the entrance to our alimentary canal, and tests the food not only qualitatively but also quantitatively from the standpoint of molecular concentration. To this function of the sense of taste we may give the name osmotactic, and it is undoubtedly to the possession by the sense of taste of this osmotactic character that the stomach mucosa is shielded from exposure to foods whose osmotic pressure is far above that of the environment to which the cells are normally accustomed. When for any reason a highly hypertonic fluid is admitted to the stomach, then vomiting (or sometimes diarrhoea) is the result. This is well seen after the ingestion of strong salt solutions, large quantities of sweetmeats or strong peptone solutions, or over-indulgence in alcoholic or strongly saccharine beverages. In the process of mastication and swallowing, the salivary glands are stimulated to the pouring out of a copious secretion, and the organism has developed here, too, another mechanism to aid in the dilution of the stomach contents—namely, the sense of thirst, the proper satisfaction of which, by the ingestion of a sufficient quantity of water, tends to the dilution and consequent lowering of the osmotic pressure of stomach contents. If these protective mechanisms fail in carrying out their object, then the organism responds by rejecting the contents of the stomach altogether by the reflex mechanism of vomiting.

Thus in man, at any rate, and undoubtedly in the case of the other mammals, the maintenance of a constant osmotic pressure of the blood by means of the kidneys and excretory organs is in a remarkable manner and to a considerable degree aided by the possession by these higher animals of the senses of taste and thirst. (Of man and mammals we can speak with certainty, although it is legitimate from common experience to postulate that all vertebrates at least possess these senses too.) The power to vomit is possessed by most animals. Amongst ruminants and solipeds it is a rare occurrence, but, after all, the nature of the food of these animals would undoubtedly exempt them from the necessity of ever rejecting the contents of the stomach. But with man and the carnivores particularly, the nature of their food, particularly the liability to putrefaction and ptomaine formation, renders the existence of the power to vomit a necessity, altogether excluding considerations of the osmotic pressure of stomach contents, which pertain chiefly to man, who, by an abuse of his intelligence, perpetrates dietetic errors from which the lower animals are protected by their instinct, and senses of taste and smell.

In connection with those hypertonic fluid foods which are normally admitted to the stomach of man, the following observations of mine are of interest. A definite volume of beer was taken which gave a Δ of 2.246, evaporated to dryness and then calcined. The ash was then taken up in the same volume of distilled water, and dissolved almost completely, leaving a small residue of calcium carbonate, which probably existed in the beer as the soluble calcium salt of some organic acid. This watery extract gave a Δ of 0.026°C.; and similarly with the juice of the orange—

Δ of juice - - - - -	0.990
Δ of aqueous extract of ash - -	0.132

These experiments are analogous to what occurs in the body. The saccharine and alcoholic constituents of the food are rapidly absorbed and burnt off, or stored in the body as inert substances (cf. glycogen), while the saline constituents are left to play their part in the osmotic pressure phenomena in the body. Thus we see that the kidney is constantly called upon (in marine forms always and generally in land mammals as well) to excrete inorganic salts, which tend to produce a rise in the osmotic pressure of the blood, and thus the urine is generally hypertonic. Prima facie, this means work done, and hence in metabolism experiments this work done should be included in the energy balance-sheet, for in some cases the amount of energy thus expended may attain considerable dimensions when converted into terms of heat value or mechanical work.

We thus see that in the evolution of the race there has been a steady growth of the tendency of the individual to become independent of its environment (and therefore not compelled to change in response to alterations in that environment) by means of maintaining through the co-ordinated and integrative action of all its organs, constancy in the action of its vital parts.

The removal of its vital organs from the disturbances of function which must of necessity follow alterations in the physical and chemical properties of their environment, which in the higher animals are dependent on those of the circulating fluid, was the first great advance, and ensured for the organism the better and more efficient action of these organs, and afforded a distinct impetus to higher specialisation and greater independence of external environmental change. Thus, the beginning of the development of the firm resistant bony skeleton in place of the soft cartilaginous framework, and the formation of a high type of tissue from a simple one which this advance implies, most probably began to take place at a time in the history of the race when the cartilaginous fish was leaving the sea and taking to the mud of estuaries, where it most probably also developed the mechanism for maintaining the salt ratios and osmotic pressure of its blood a constant.

The sea water which is contained in the oceans of the present day gives a Δ of about 2.3°C. Bottazzi (1) gives a long series of determinations of the Δ of the body-fluids of many marine forms, and his results show that this Δ is approximately that of the sea-water environment in the case of coelenterates, echinoderms, crustaceans, gastropods, cephalopods amongst the invertebrates, and the elasmobranch fishes amongst the vertebrates.

Then there is a jump, and the blood of teleosts is found to give a Δ of about 1, and my own observations on the blood of the barracouta, a teleost inhabiting Australian waters, confirms these results. (Δ of water of Hobson's Bay about 2.1.) The next sea animals that we come to are the sea turtles, with a Δ of 0.7, and the next the sea mammals—seals, dolphins and whales. The determinations of the Δ of the blood of these animals have been made by Portier (11), Rodier (12), and Jolyet (5), on the blood of animals which had been recently killed. Post-mortem decomposition may explain to a small degree the large differences between the figure (0.59) for terrestrial mammals, and the figures 0.64—0.71 for seals (Portier, 11), 0.8 for dolphins (Jolyet, 12), and 0.74 for whales (Rodier, 5). Portier (11) has also shown that the Δ of the blood of marine birds is very little greater (0.63—0.69) than that of land birds (about 0.616, Bottazzi, 1).

With regard to fresh-water animals, the results are interesting. Of invertebrates, I have determined the Δ of the body-fluid of *Astacopsis bicarinatus*, which I find to be 0.616. Fredericq (4) gives 0.8 for the body-fluid of *Astacus fluviatilis*, while of vertebrates Bottazzi (1) gives:—

Frog *(Rana esculenta)* - - -	0.465
Tortoise *(Emys europaea)* - -	0.44-0.48

My own figures for the serum (from blood obtained by cannulisation of the carotid artery in the neck) of tortoises, *Emydura macquariae* (Murray tortoise), at two different periods of the year were 0.560 (June) and 0.550 (September).

The blood of various fresh-water teleosts, according to Hamburger and Dekhuyzen (quoted by Bottazzi 1), gives about 0.5, while my own figure for the serum expressed from the blood clot obtained from the vena cava of the Murray cod *(Oligorus macquariensis)* is 0.650, which is perhaps a little high, due to post-mortem decomposition.

Of terrestrial animals below true mammals I have two different determinations of the Δ of blood of *Echidna hystrix* 0.624, of an animal during hibernation, 0.600 of an animal when awake, and *lizard* 0.639, and Bottazzi gives 0.616 as the average Δ of the blood of land birds.

We are thus confronted with the following facts:—

(1)—Of marine animals, all forms below and including the elasmobranch fishes possess a body fluid whose Δ is approximately that of the medium in which they live (Δ of sea-water about 2.3°C.), and Bottazzi (1) has shown that these animals are poikilosmotic—i.e., the osmotic pressure of their body fluids follows (within limits) that of the environment.

(2)—The blood of teleostean marine fishes gives a Δ of about 1°C.

(3)—The blood of marine reptiles gives a Δ of about 0.7°C.

(4)—The blood of marine birds has an osmotic pressure very little higher than that of land birds (about 0.62—0.69°C.)

(5)—Of marine mammals, seals (belonging to carnivora) give Δ very little above that of land mammals, and whales (cetacea) a somewhat larger Δ than seals and land mammals.

(6)—All terrestrial vertebrates examined, viz., reptiles (lizard), birds, echidna, mammals, possess a circulating fluid which gives a Δ of about 0.6°C.

(7)—Of fresh-water animals the crustacean gives a Δ of 0.6 (0.8 according to Fredericq for *Astacus fluviatilis*), amphibia about 0.45, reptiles (tortoises) about 0.55°C., and fishes (teleosts) 0.5—0.69°C.

There are thus seen to be certain "jumps" in the figures given, which afford interesting food for reflection.

Firstly, with regard to marine animals, the question arises, why should the Δ of the blood of the teleosts differ in such a remarkable manner from that of the elasmobranchs? The acquisition of a bony skeleton by the teleost at once proclaims him a superior individual to the soft cartilaginous elasmobranch. This fact combined with the indubitable fact that the environment of terrestrial life conduces in every way to a higher evolution, and the existence of the swimming bladder in these fishes, to my mind, lead to the conclusion that a cartilaginous fish passed through the stages of a mud fish, and ultimately lived in swamp, where it developed a bony skeleton, and meanwhile also developed the mechanism of maintaining the osmotic pressure of its blood constant. Some of these new individuals (bony fish) then wandered back to the sea, their original home, and the osmotic pressure of their blood gradually rose, but still has remained fairly constant near the original value. Others betook themselves to the fresh-water streams, and have maintained through the ages a blood whose osmotic pressure is approximately (possibly a little lower than) that of the teleost when it (as I presume) wandered back to the water. The sea turtle we can imagine to be a descendant of an individual which was evolved from this paludial teleost, and which wandered back to the sea at a later period than that in which the teleost returned to the sea.

The blood of marine birds and mammals is naturally approximately that of the land birds and mammals, since these animals had taken to the sea in comparatively recent (geological) times, and their organisation had been so constituted, that they have been able successfully to withstand the strain which their new environment has thrown on the lining membrane of the alimentary tract and on the cutaneous structures and kidneys in the maintenance of an osmotic pressure of their body fluid to which the protoplasm of their tissues had become attuned in the course of evolution.

In support of these conclusions may be brought the facts of palaeontology and zoology. The fishes of the cambrian and silurian ages were elasmobranch. These animals have a cartilaginous skeleton, and do not possess a swim bladder, although a few do possess a rudimentary diverticulum opening from the oesophagus. In the devonian period the dipnoi appear. The swim bladder is well developed, and the unused gills are degenerating. The animal is preparing for a terrestrial life, and we at once see the beginning of the development of the organs of phonation (the modern representatives, the mud fish of Queensland *(Ceratodus)* possessing a glottis arrangement in connection with the neck of the air sac), thus affording the animal the best means of communication with his fellows, and thus conducing towards a gregarious existence which is the basis of man's civilisation. In the strata of this era, too, are the fossil remains of the primitive amphibia, which most probably arose from these dipnoi. Then from the dipnoi evolved the holostei which existed in permian and triassic times, and were prominent in jurassic times. These no doubt passed on into the ganoids, which gave rise to the primitive teleostei which exist in the upper triassic and cretaceous ages and reached their full development in the upper eocene. By this time, no doubt, these fish had returned to the water, some to the sea, others to the fresh water streams, and in this return the swim bladder, now no longer needed for respiratory purposes, degenerated until in the higher teleosts the duct, which had been gradually shifting more dorsally (9), totally disappears, and the swim bladder remains in these animals a closed cavity, and is used by the animal for an altogether different purpose (that of a "sounding organ" and as a float). What determined the return of the evolving teleosts to the water cannot be stated, but the fact that fresh water fish belong exclusively to the teleosts with the exception of one or two genera of stingrays in the rivers of tropical America (10) (which, after all, may be "accidental inclusions"), to my mind is strong argument in favour of this idea. Moreover, the development of the bony skeleton and the possession of a circulating fluid whose physical constants could be maintained irrespective of alterations in those of the environment enable these teleosts to migrate and pass from sea water into estuaries and up rivers, as is done by such a fish as the salmon in the breeding season, feats which would be practical impossibilities for the poikilosmotic elasmobranch.

Of course in considering this problem due consideration must be given to the method of "give and take" which is exemplified in all evolutionary processes. Thus could be explained any unaccountable differences in vascular development or higher development in parts of the nervous system in some of the lower animals, and as analogies may be taken the loss of the alimentary canal in intestinal worms and the degeneration of the organs of smell in man when he assumed the erect posture.

The skeletons of whales appear in the tertiary periods (eocene and miocene), and since that time the whales have probably given in a little in the constant struggle against the concentration of their body fluid by the surrounding medium. The seals probably appeared later than the whales, and possibly migrated to the sea later. This would account for the closer connection between the Δ of the blood of seals and the Δ of the blood of terrestrial mammals than holds in the case of the blood of whales. Marine birds are, probably by their aerial life and migratory habits (and hence ability to obtain fresh water from pools and rivers on land as suggested by Rodier, 12), removed from the necessity of "giving in" to the tendency of their food to render the body fluids hypertonic.

On the other hand, from reptile and bird to mammal, the osmotic pressure of the circulating fluid of the terrestrial animal is about the same (0.6). But why should the Δ of the body fluid of the fresh-water crustacean be much greater than that of amphibian and amphibious reptile (tortoise)? To me it appears that we have here evidence of a change of habit similar to what I imagine occurred to the fishes. A crustacean wandered in comparatively recent times (Ortman (8), has shown that fresh-water crabs and crayfish did not appear till the upper tertiary) from the sea to the land and rivers, and finding food abundant and the environment favourable, remained there. In his new environment this poikilosmotic creature responded to the change in concentration of the medium in which he lived, and although the osmotic pressure of his body fluid has not yet reached that of the land animals derived from the primitive fish, it has, however, reached a very low figure indeed, when we take into account the fact that its tissues were originally attuned to an environment whose osmotic pressure was three or four times its present value. A similar line of reasoning will explain the lower osmotic pressure of the blood of the amphibia and to a small degree some amphibious reptiles.

The recently published work of Macallum (7) is of additional interest in this connection.

In contrasting the composition of the water of the oceans of the present day with the composition that the waters of the ocean at various geological epochs must have possessed, as determined from geological evidences, Macallum (6) had shown that the sodium content had rapidly increased, and the magnesium content had slowly increased, while, since rivers had formed, calcium and potassium had remained practically constant.

Macallum in his recently published paper (7) gives analyses of the blood serum and body fluid of various animals, and has also drawn up a table which gives the proportions of potassium, calcium, and magnesium to sodium, which is taken as 100. These tables I append.

TABLE A.

	Δ	Na	K	Ca	Mg	$\frac{{}^{*}\mathrm{Mg}}{\Delta} \times 10$
Sea-water - - -		0.988	0.035	0.052	0.193	
Limulus (*Polyphemus*) -	2.04	0.8885	0.0499	0.0361	0.0996	488
Lobster (*Homarus americanus*)	1.78	0.9034	0.0338	0.0439	0.0156	88
Dogfish (*Acanthias vulgaris*)	2.035	0.5919	0.0273	0.0161	0.0146	71
Cod (*Gadus callarius*) -	0.71	0.4161	0.0396	0.0163	0.0059	83
Pollock (*Pollachinus virens*)	0.825	0.4145	0.018	0.0129	0.00608	73
Mammals - - -	0.6	0.425	0.0226	0.011	0.004	67

*As calculated from Macallum's figures.

TABLE B.

	Na	K	Ca	Mg
Ocean	100	3.66	3.84	11.99
Aurelia (*Flavidula medusa*)	100	5.18	4.13	11.43
Limulus (*Polyphemus*)	100	5.62	4.06	11.20
Dogfish (*Acanthias vulgaris*)	100	4.61	2.71	2.46
Lobster (*Homarus americanus*)	100	3.73	4.85	1.72
Pollock (*Pollachius virens*)	100	4.33	3.10	1.46
Cod (*Gadus callarius*)	100	9.506	3.93	1.41
Dog	100	6.86	2.52	0.81
Mammal	100	6.69	2.58	0.80

The latter table gives us some idea of the changes in salt ratios which have been taking place in the course of evolution. Ignoring the ratios of calcium and potassium, which do not show any marked variation, and confining our attention to the proportion of magnesium to sodium, we see that in the medusa (*Aurelia flavid.*), and the king crab (*Limulus*), the proportions are about the same as in sea-water. In the elasmobranch the proportion is 2.46 : 100, while the lobster (*Homarus americ.*) gives the proportion 1.72 : 100, teleosts (pollack and cod) give 1.46 and 1.41 : 100 respectively, while mammals give 0.81 : 100.

Magnesium is an element which exerts a markedly toxic action on protoplasm, and it is only natural to suppose that in the course of evolution not only would there be a fight against any alterations in the osmotic pressure and salt ratios of the environment, but that if the organism were compelled to yield, it would yield more in the case of the less toxic than in the case of the more toxic substances. Now the Δ of an animal's body-fluid is due to the presence in solution of organic bodies and salts (and their ions), and it may be assumed that the salts and their ions account for the greater part of this Δ.

On looking at the ratio Mg/Δ for the body fluid of various animals, we see that the dogfish, pollock and mammal give approximately the same ratio, the lobster a slightly higher figure, while the limulus gives a figure approximating that of sea-water.

Thus we see that, although the lobster and elasmobranch have not been highly enough evolved to resist the concentration of their body fluid, which the increasing concentration of their environment would tend to produce, they have to a great degree been able to withstand the accumulation of the toxic magnesium in their body fluid.

The postulation of an extra-marine (fluviatile?) existence for the ancestors of the lobster (as advanced supra) would account for this great difference between limulus and the lobster.

We thus see that the animal economy at the elasmobranch stage of its evolution is capable of resisting entry of toxic chemical substances into its organisation, but not of withstanding to any degree the physical forces of osmosis, so that, although the animal's economy can to some degree determine the salt ratios (and salt concentration too, as pointed out by Bottazzi, 2), in its body-fluid, it is unable to resist the concentration of this fluid by the osmotic pressure exerted by the environmental ocean.

A table showing the genealogical relationships of the fishes and higher vertebrates in accordance with the foregoing considerations and postulations is appended. (Appendix C.)

My thanks are due to Professor W. A. Osborne, under whose guidance this work was carried out.

APPENDIX A.

Osmotic Pressure of Liquid Foods.

(Centigrade scale employed throughout.)

(Portions of the following results were published in the Biochemical Journ., 1909.)

Beverages.

Coffee (2 tablespoonfuls of sugar in ordinary breakfast cupful).—

	Δ
(1) - -	0.341°C.
(2) - -	0.343°C.

Tea infusion (2 teaspoonfuls (about 12 c.c.) of tea leaves in 200 c.c. boiling water, allowed to infuse 5 minutes).—

	Δ
(1) - -	0.052.
(2) - -	0.049
(3) - -	0.050

Tea (100 c.c infusion, 50 c.c. water. 25 c.c. milk, 10 grms. sugar). Tasted "just nice."—

(1) - -	0.457
(2) - -	0.458
(3) - -	0.456

Tea (Second infusion, made with 200 c.c. more water added to leaves from infusion, and allowed to stand 35 minutes).—

(1) - -	0.026
(2) - -	0.025

Lemon juice (As used in Melbourne Hospital).—Strained juice of lemon (1 lemon) 33 c.c. in 250 c.c. distilled water.—

(1) - -	0.126
(2) - -	0.125
(3) - -	0.122

100 c.c. of diluted juice and 1 teaspoonful (5 grms.) cane sugar added. Tasted "just right."

(1) - -	0.487
(2) - -	0.485

"*Lime Juice and Soda*."—(Marchant and Co., Melbourne.)—

(1) - -	1.268
(2) - -	1.265

Beer. (Carlton XXX. Draught Beer).—

(A)	(1) - -	2.407
	(2) - -	2.409
(B)	(1) - -	2.246
	(2) - -	2.250

30 c.c. of specimen (B) were taken and evaporated to dryness and calcined. Ash extracted with 30 c.c. distilled water. There was a small undissolved residue composed chiefly of calcium carbonate, which was probably derived from soluble salts of organic acids in the beer.

Ash Extract.—

(1) - -	0.026
(2) - -	0.026

Wine. (Cheap Australian claret). Cooled to —5°C, but ice would not separate out.

Wine.—Kept between 77°C and 80°C for 35 minutes, and then boiled briskly for about seven minutes to get rid of alcohol.

75 c.c. wine subjected to this treatment yielded 45 c.c.

(1)	-	-	3.240
(2)	-	-	3.238
(3)	-	-	3.241

Foodstuffs.

Treacle.—Diluted with water to 1 in 7, and this solution gave—

Δ
1.730

Peptonised Milk.—Benger's peptonised milk, as used at the Melbourne Children's Hospital, Carlton, Melbourne, Victoria.

Benger's Milk "A."—(Milk 3, Water 1, peptonised 20 minutes. Boiled, sweetened with cane sugar about 1 oz. to 1 pint milk.) One drop gave pink biuret reaction.

(1)	-	-	0.652
(2)	-	-	0.656

Benger's Milk "B."—(Milk, 2, water 1, peptonised 20 minutes. Sweetened.)

(1)	-	-	0.630
(2)	-	-	0.628
(3)	-	-	0.626

Peptonised Milk.—(Milk 4, water 1, peptonised 20 minutes.)

(1)	-	-	0.548
(2)	-	-	0.546

Soups.—An ordinary soup which had been served up, but rejected as unpalatable on account of salt taste.

(1)	-	-	1.984

Soups.—

A vegetable soup was made of the following ingredients:—

Carrot	-	-	-	100 grms.
Parsnip	-	-	-	110 ,,

Turnip	55 grms.
Spring onion	47 ,,
Celery	25 ,,
Parsley	12 ,,
Water (distilled)	1500 c.c.

Brought to boil and kept simmering for 2¼ hours. Strained. Salted to different degrees.

Vegetable Soup Plain.—

(1) - - 0.374
(2) - - 0.373
(3) - - 0.372

Vegetable Soup Salted.—

A.	Soup + salt to 4 per cent.		2.757
B.	Soup + salt to 2 per cent.		1.536
C.	Soup + salt to ⅘ per cent.	(1)	0.851
		(2)	0.856
D.	Soup + salt to ¾ per cent.		0.780
E.	Soup + salt to ⅓ per cent.	(1)	0.586
		(2)	0.584
		(3)	0.582

The verdict of the taster was: The unsalted vegetable soup possessed a very flat and unsatisfactory taste. A, B, C and D distinctly too salty. A and B distinctly unpleasant taste. E was about right.

Beef Tea.—Made with about 6 c.c. meat extract (Fitzroy Brand, Queensland manufacture) in 1000 c.c. distilled water.

Beef Tea Plain.—

(1) - - 0.141
(2) - - 0.139
(3) - - 0.140

Beef Tea Salted.—

A. Beef tea + salt to 2.5 per cent.

(1) - - 1.626
(2) - - 1.626
(3) - - 1.625

B. Beef tea + salt to 1.25 per cent.

(1) - - 0.882
(2) - - 0.887
(3) - - 0.886

C. Beef tea + salt to 0.625 per cent.
(1) - - 0.546
(2) - - 0.544
(3) - - 0.543

D. Beef tea + salt to 0.416 per cent.
(1) - - 0.419
(2) - - 0.416

Sample C was much the tastiest, just salted to taste; A and B having too much salt, and sample D and the original not enough salt.

Beef tea made with about 6 c.c. meat extract in 1000 c.c. boiling distilled water.—

0.160

Beef Tea Salted.—Salt added till the flat and unsatisfying taste of the beef tea was abolished, but still no salty taste perceptible.

Taster A. (1) - - 0.330
(2) - - 0.331
Taster B. (1) - - 0.329
(2) - - 0.330

Beef Tea Over-Salted.—

1.922

Sugar Solutions.

Dextrose solution, 100 c.c. taken into mouth in sips of 25 c.c., each sip kept in mouth half minute, spat out; in half minute another sip taken, kept in half minute, spat out; and so on for four sips.

10 per cent. dextrose solution.

Δ

1.156

10 per cent. dextrose solution salivated.
(1) - - 1.068
(2) - - 1.066

5 per cent. dextrose solution.

0.566

5 per cent. dextrose solution salivated.

(1) - - 0.536
(2) - - 0.532
(3) - - 0.534

Cane sugar solution, 20 grms. in 150 c.c. (13.3 per cent.), 100 c.c. treated in similar manner as dextrose solution above, 7 c.c. saliva were added by this process to the 100 c.c. sugar solution, and there was an after secretion for several minutes.

Cane sugar solution (13.3 per cent.).

0.868

Cane sugar solution salivated.—

(1) - - 0.788
(2) - - 0.792

Fruit Juices.

Lemon.—Weight 140 grms. Peel and connective structure 90 grms. Yielded 40 c.c. strained juice.—

Δ

(1) - - 0.937
(2) - - 0.940
(3) - - 0.939

Orange.—A. Orange 135 grms. Yielded 50 c.c. strained juice.

(1) - - 1.100
(2) - - 1.101
(3) - - 1.100

B. 225 grms. peeled orange. Yielded 110 c.c. strained juice (pressed by hand).

(1) - - 0.990
(2) - - 0.992

30 c.c. juice evaporated to dryness and calcined, and ash taken up in 30 c.c. distilled water. There was a small undissolved residue, composed chiefly of calcium carbonate.

Ash extract.—

(1) - - 0.134
(2) - - 0.132

Pineapple juice.—From fresh Queensland pineapple.

(1) - - 1.462
(2) - - 1.464
(3) - - 1.460

Cocoanut "milk."—(About 150 c.c. were yielded by the nut.)

(1) - - 0.521
(2) - - 0.518
(3) - - 0.518

Peaches.—300 grms. of peaches (5 stoneless peaches) yielded 180 c.c. strained juice.

(1) - - 1.090
(2) - - 1.088
(3) - - 1.088
(4) - - 1.090

Apricots and plums simply formed a pulp, but no juice was obtainable.

Cherry plums.—500 grms. cherry plums yielded 250 c.c. strained juice.

(1) - - 1.031
(2) - - 1.034
(3) - - 1.030

Tomato.—350 grms. tomato yielded 80 c.c. juice.

(1) - - 0.526
(2) - - 0.528
(3) - - 0.526

Apples.—300 grms. apple (ripe) yielded 30 c.c. juice.

(1) - - 1.196
(2) - - 1.192
(3) - - 1.195

Gooseberries.—300 grms. yielded plenty of pulp, but only 10 c.c. juice.

(1) - - 1.353
(2) - - 1.350
(3) - - 1.352

Cherries.—250 grms. yielded 105 c.c. juice.

(1) - - 2.246
(2) - - 2.244
(3) - - 2.243

Grapes.—250 grms. yielded 160 c.c. juice.

(1) - - 3.248
(2) - - 3.254

Saline Aperients.

Magnesium sulphate solution.—(15 grms. in 100 c.c.).

Δ
1.136

Balanced saline aperient.—The stronger one as recommended by Professor W. A. Osborne in a paper in the Intercolonial Medical Journal of Australasia, July 20, 1909.

(1) - - 0.864
(2) - - 0.862
(3) - - 0.861

Saliva produced from sucking confectionery.—Barley-sugar stick (about 12 grms.) sucked for fifteen minutes led to production of 72 c.c. saliva.

(1) - - 1.008
(2) - - 1.006

Saliva from about 30 grms. boiled cane sugar, sweetmeat, 100 c.c.

(1) - - 1.488
(2) - - 1.484

The Beckmann freezing point method was employed throughout.

A mixture of ice and salt water was used to produce the requisite cold, but care was taken to prevent excessive supercooling.

In none of the recorded readings was the degree of supercooling more than about 1.5°C.

Crystallisation was started by inoculation with a fragment of frozen distilled water.

The stirring was carried out by a simple clock-work mechanism.

In the case of soups the "salting to taste" was carried out by a laboratory attendant, who was not aware of the purpose of the research.

APPENDIX B.

COMPARATIVE CRYOSCOPY OF THE BLOOD.

(Portion of the following results have been published in the Biochemical Journal, 1911.)

(*The results of other authors are indicated by references.*)

	Δ	
Land Mammals—		
Sheep (Defibrinated blood obtained from slaughter yards)	0.59	
Rabbit	0.59	
Echidna hystrix.—Hibernating (Septr.) (A)	(1) 0.624	
	(2) 0.622	
Echidna hystrix.—Hibernating (May) (B)	(1) 0.600	
	(2) 0.600	
Sea Mammals—		
Seals (*Phoca barbata*)	0.64-0.66	Portier (11)
Whales (*Phocaena communis*)	0.74	Rodier (12)
Dolphin (*Tursiops tursio*)	0.83	Jolyet (5)
Land Birds—		
Domestic fowls	0.616	Bottazzi (2)
Marine Birds—		
Larus glaucus	0.69	Portier (11)
Uria troile	0.66	Portier (11)
Eider	0.65	Portier (11)
Fulmarus glacialis	0.63-0.69	Portier (11)
Sea Reptiles—		
Sea Turtle	0.7	Bottazzi (1)
Thalassochelys caretta	0.61	Bottazzi (1)
Land Reptiles—		
Tortoises. *Emys. europea*	0.474	Fredericq (4)
Emydura macquaria A	(1) 0.559	
	(2) 0.561	
	(3) 0.560	

	(B) (1)	0.550	
	(2)	0.545	
	(3)	0.550	
Lizard. Mixed blood of *Egerna cunninghami*	(1)	0.639	
and a species of *Tiliqua*	(2)	0.637	
Amphibia—			
Rana esculenta		0.465	Bottazzi (1)
Fish—Elasmobranchs (sea-water)—			
Torpedo marmorata		2.26	Bottazzi (1)
Mustelus vulgaris		2.36	Bottazzi (1)
Teleosts (sea water)—			
Charax puntazzo		1.04	Bottazzi (1)
Cerna gigas		1.035	Bottazzi (1)
Crenilabrus pavo		0.74-0.76	Bottazzi (1)
Box salpa		0.82-0.88	Bottazzi (1)
Barracouta	A (1)	0.979	
	(2)	0.978	
(*Thyrsites atua*)	B (1)	0.976	
	(2)	0.980	
Teleosts (fresh water)—			
Anguilla vulgaris		0.58-0.69	Bottazzi (1)
Barbus fluviatilis		0.475-0.558	Bottazzi (1)
Perca fluviatilis		0.512	Bottazzi (1)
Murray Cod (*Oligorus macquariensis*)		0.642	
		0.660	
		0.650	
Cephalopods—			
Octopus macropus		2.24	Bottazzi (1)
Crustacean (Marine)—			
Maja squinado		2.36	Bottazzi (1)
Homarus vulgaris		2.29	Bottazzi (1)
Crustacean (Fresh water)—			
Astacus fluviatilis		0.80	Bottazzi (1)
Astacopsis bicarinatus	(1)	0.616	
	(2)	0.611	
	(3)	0.618	

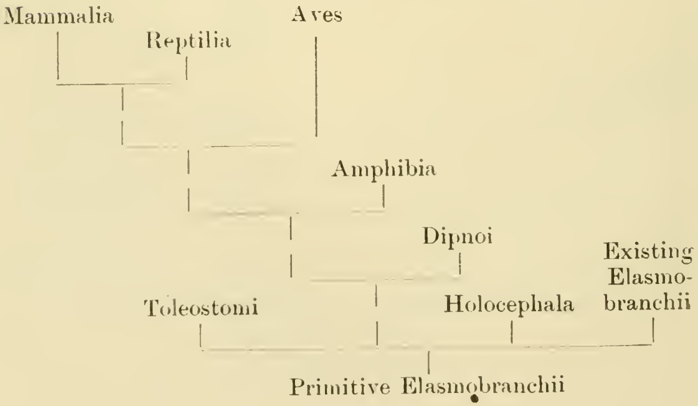
APPENDIX C.

From Parker and Haswell (6) and the Cambridge Natural History, Vol. VII., ed. by S. F. Harmer and A. E. Shipley, and Ortmann (8).

Eozoic		Archean				
Palaeozoic Primary	Newer Palaeo	Cambrian	Elasmobranch			
		Ordovician				
		Silurian	Elasmobranch			
	Older Palaeo	Devonian	Holocepheli	Chondrostei	Dipnoi	Amphibia
		Carboniferous			Dipnoi	
		Permian			Holostei	Reptiles
Mesozoic Secondary		Triassic	Mammals		Holstei	
		Upper Triassic				Teleost
		Jurassic	Mammals	Birds	Holstei	
		Cretaceous		Crab		Teleost
		Upper Cretaceous		Fresh-water Crab		
Cainozoic Tertiary		Eocene	Whales			Teleost
		Oligocene				
		Miocene	Whales			
		Pliocene				
		Postpliocene				

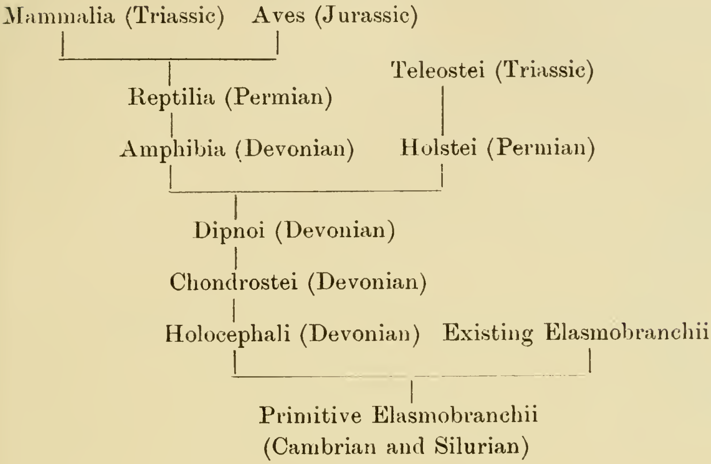
GENEALOGICAL TABLE

(according to Parker and Haswell).



TABLE

modified in accordance with considerations contained in the foregoing paper.



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[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XIX.—*Contributions to the Flora of Australia, No. 18.*[1]

BY

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MARINE BIOLOGICAL LIBRARY WOODS HOLE MASS.

(With Plates LII-LVI.).

[Read 12th October, 1911.].

Bartsia latifolia, Sibth. and Sm. "Common Bartsia." (Scrophulariaceae.)

Cheltenham, Victoria, J. R. Tovey, 23/9/1911.

A form with white flowers. The plants occurred in a single large patch mixed with plants having flowers of the normal colour, so that it cannot be a peculiarity due to the soil. The peculiarity does not appear to have been noticed before in this plant, and it will be of interest to note whether white-flowered forms reappear in the same locality and spread to new ones.

Battarea phalloides, Dicks. (Pers. Syn. 129, t3, f. I. Sacc. Syll. VII. 195). (Fungi. Basidiomycetes)

Growing in sand under *Leptospermum laevigatum,* North Brighton, Victoria, C. French, Jnr., 6/8/1911.

New locality. Only previously recorded in Victoria from the North-West. Also found in West and South Australia.

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[1] No. 17 in Proc. Roy. Soc. Victoria, vol. xxiv. (n.s.), 1911, p. 61.

BOSSIAEA MICROPHYLLA, Sm. "Small-leaved Bossea." (Leguminosae.)

Eastern slope of Brisbane Ranges, P. R. H. St. John, 17/9/1911.

The most southerly locality in Victoria hitherto recorded for this species.

CAPPARIS UMBONATA, Lindl. (Capparideae.)

Napier Broome Bay, North-West Australia, G. F. Hill, Dec., 1909, No. 32.

The specimen has adult fruits, and Bentham apparently had unripe fruits only for examination. Hence a description is appended.

Fruit of *Capparis umbonata.*—Fruit usually about 1½ inches in diameter. Glabrous, woody, indehiscent, globular when ripe, with no protuberance on top. Seeds about 5 to 10 embedded in a hard, almost woody, pulp. Stipes 2½ to 3 inches long.

CASUARINA LUEHMANNII, R. T. Baker. "Bull Oak." (Casuarineae.)

Growing on plain between Brisbane Ranges and Parwan, P. R. H. St. John, October 17th, 1911.

The furthest southern locality recorded for this species in Victoria.

CHLORIS ABYSSINICA, Hochst, "Abyssinian Rhodes-Grass" (Gramineae).

Pearcedale, May, 1911. Ch. Cox.; Kerang, Victoria, July, 1911, per Law, Somner and Co.

This useful grass, a native of Abyssinia, has been frequently cultivated, and is now evidently becoming naturalised in this State.

CORYPHA, L. (Muss. Cliff. 11. (1736), Gen. Ed. 1.), (Palmae).

CORYPHA ELATA, Roxb. in Hort. Beng., 25; Fl. Ind., 176. Determined by O. Becarri.

Lower Gilbert River, Queensland, J. O. Rully.

This characteristically East Indian species is the sole representative of the genus in Australia.

ERYTHROSTACHYS PROLIFERA (T.Ag.). J. White. (Algae. Rhodomelaceae.)

Encounter Bay, South Australia. D. Hussey.

A new genus of *Alga* named by T. Agardh, but undescribed. This specimen was sent to Major Reinboldt at Itzehoe, and returned by him as a genus unknown to him, and also to the Keeper of the Agardh Herbarium at Lund. It is hoped that by publishing this description the search for further material of this interesting plant may be stimulated.

This specimen is purely vegetative, no trace of reproductive organs being visible. It apparently belongs to the family *Rhodomelaceae.* Frond stipitate, the stalk cylindrical, and in this specimen about 5 inches long, and in its thickest portion about half a line in diameter. The frond is prolifically branched, the branches arising in lateral groups alternately along the frond, at intervals of from one to two lines. These primary branches are usually less than an inch in length, are filiform and branch rather freely to form secondary branches alternately.

The secondary branches give off numerous short tertiary branches alternately, which tend to become crowded towards the tip, where the secondary branches become spirally swollen. The tertiary branches soon after their origin divide usually into two branches, which taper to a rather fine point.

The whole plant is covered externally by a rather thick, gelatinous sheath, the same material forming the intercellular material. The tertiary branches are strongly articulate.

The stalk of the frond, primary and secondary branches, is solid, and composed of a large number of somewhat elongated cells, about 3 to 6 rows of the more peripheral of which are less regular and filled with highly coloured, apparently structureless contents, the cells tend to become more elongated towards the centre, and are completely filled with granular contents which are probably physodes and impart a cellular appearance to the cell contents. The tertiary and ultimate branches are only one cell thick.

EUCALYPTUS CAMPHORA, R. T. Baker. "Sallow or Swamp Gum." (Myrtaceae.)

Sutherland's Creek, about six miles south of Steiglitz, Victoria. P. R. H. St. John. 16/9/1911.

A new locality in Victoria for this species.

GASTROLOBIUM ROTUNDIFOLIUM, Meissn. Leguminosae.

Strawberry, West Australia, Dr. Stoward, 4/9/1911.

The only specimens of this species in the National Herbarium previously were those of Drummond, No. 99, from West Australia, without detailed locality.

GLADIOLUS GRANDIS, Thunb. "Large-flowered Gladiolus." (Irideae.)

Eltham, Victoria, P. R. H. St. John, 23/9/1911.

A native of South Africa. May be classed as a garden escape, apparently in process of naturalisation.

GREVILLEA LANIGERA, A. Cunn., and G. ROSMARINIFOLIA, A. Cunn.

In Bentham's Flora Australiensis, Vol. V., page 444, four species are recognised under these heads—namely, *G. lanigera*, A. Cunn.; *G. ericifolia*, R. Br.; *G. divaricata*, R. Br.; and *G. rosmarinifolia*, Cunn.—but Bentham suggests that the last three species may be all referable to a single one. Baron Mueller in the last Census drops *G. ericifolia* and *G. divaricata*, but gives no indication as to which species they are referred. The leaf characters are highly variable, and by themselves could not be relied on to distinguish more than one species with leaves varying, as regards hairiness, pointed character, breadth and amount of longitudinal inrolling.

In *G. lanigera*, A. Cunn. (*G. ericifolia*, R. Br.), the ovary is densely villous. In *G. rosmarinifolia*, A. Cunn. (*G. divaricata* R. Br.), the ovary is glabrous, or with a small tuft of hairs at the base on the upper side. Both species run close together, but there appears on the whole to be a general external difference of facies, difficult to express in precise or definite terms. Hence it seems advisable to retain two species as above for this set of plant forms, but certainly not more than two, and to refer *G. ericifolia* to *G. lanigera*, *G. divaricata* to *G. rosmarinifolia*.

GULUBIA, Becc. in Ann. Jard. Buitenzorg. 11.131 (1885). (Palmae.) G. Ramsayi, Becc., in Webbia 111 (1910), p. 159, f. 6a. Determined by O. Beccari.

Port Essington, North Australia.

This Malayan genus apparently extends to North Australia, and may possibly be also represented there by other species yet to be discovered.

HYMENOPHYLLUM PELTATUM (Poir), Desv. (H. WILSONI, Hook.) (H. UNILATERALE, Willd.) (Filices.)

Cradle Mountains, Tasmania, C. Sutton, January, 1911.

This appeared at first to be possibly a new species allied to *H. tunbridgense*, Sm., and *H. multifidum*, Sw., partly on account of the regular occurrence of the sori in pairs on the upper surfaces of the axils of the pinnules. Later specimens showed that the sori also occur singly, and that paired sori occur in specimens originally referred to a variety *Wilsoni* of *H. tunbridgense*, but now generally recognised as a distinct species as above. The plant differs from *H. tunbridgense* in having a more cylindrical and less spathulate column, and pear-shaped induzia (when adult), instead of more orbicular ones. The sporangia are perhaps more like those of *H. multifidum*, but somewhat smaller.

MALCOLMIA MARITIMA, R. Br. "Virginian Stock." Cruciferae.

Claremont, West Australia, Dr. Stoward, 6/9/1911.

This hardy annual, a native of Southern Europe, often grown in gardens, is now evidently growing wild in the Claremont district of West Australia, and may be classed an exotic not yet sufficiently established to be considered naturalised.

MATRICARIA INODORA, L. "Scentless Chamomile." (Compositae).

Coode Island, Victoria. J. R. Tovey and C. French, Jnr., October, 1908.

A native of Europe and Asia. This introduced plant may be now classed as an exotic, not yet sufficiently established to be considered naturalised.

MILLA (TRITELIA) UNIFLORA, R. Grah. "Triplet Lily." (Liliaceae.)

Apparently growing wild in Fawkner Park, Melbourne. J. W. Audas. 13/9/1911.

OLEARIA PANNOSA, Hook. "Velvet Aster." (Compositae.)

Anglesea, Victoria, A. G. Campbell, November, 1906.

Brisbane Ranges, Victoria, P. R. H. St. John, 16/9/11.

The most southerly locality in Victoria for this species hitherto recorded.

OXYLOBIUM CALLISTACHYS, Benth. (Leguminosae.)

Heath ground at Sandringham, C. French, Jr., October, 1911; Mentone, Victoria, C. R. Roberts, January, 1911.

This plant was originally supposed to be *O. alpestre*, a native species. (See Proc. Roy. Soc. Victoria, 1911, p. 71.) Material has now been obtained in all stages, and the mode of dehiscence of the pod shows it to belong to the above species, which is native to West Australia. Mr. French supposed the plant to be a garden escape. Mr. Roberts states that:—

"It grows in springy peat land about a quarter of a mile from the road, and there is no garden or cultivated ground nearer than perhaps half to three-quarters of a mile. It grows in a copse perhaps twenty feet square, shrubs up to six or seven feet high in the midst of native plants. I do not think that the *Oxylobium* could have been artificially planted there, although there are no others near it that I have seen for miles around. Its nearest point to the sea would be half a mile. As there are a number of these plants growing together I can only think that perhaps originally the seed must have been evacuated by a bird."

However it has reached the shores of Port Phillip, this plant, native to West Australia, seems to be in process of establishing itself as a "naturalised alien" so far as this State is concerned.

PIMELEA TREYVAUDI (F. v. M.), *nomen nudum*, in Vict. Nat., Vol. XI., May, 1894. (Thymelaeaceae), p. 2, Ewart and Rees.

Cudgewa, Upper Murray River, H. H. Treyvaud.

There is no record of any published description of this species, and as it appears to be a valid one, a description is appended beneath.

Small branching shrub about 12 inches in height, glabrous, or nearly so.

Leaves flat, linear to lanceolate, $\frac{3}{4}$ to 1 inch in length, lower ones shorter and narrower, with distinct intra-marginal vein, opposite.

Flower heads 7 to 8 lines in diameter, 8 to 9 bracts about the same length as flowers, ovate lanceolate, acuminate, glabrous on under surface, edges fringed with silvery hairs, which are much longer at the base than towards the tip, upper surface covered with silky hairs which are much thicker towards the base.

Flowers hermaphrodite, perianth tube about $1\frac{1}{2}$ lines long, hairy outside with tufts of longer hairs at the base, practically glabrous inside, segments about the same length as the tube. the two inner rather blunter and paler coloured than the outer, and finer in texture. Anthers oblong, connective narrow, filaments shorter than anthers and inserted near the mouth of the tube. No fruit with the specimen. It seems nearest to *P. nervosa*, but differs from it in the size of the leaves, in the number and form of the bracts, in length of the perianth tube and of the filaments.

POLYGONUM ATTENUATUM, R. Br. (Polygonaceae.)

Jones' Creek and George River, south of Roeburne, West Australia, J. Forrest, 1878.

POMADERRIS FERRUGINEA, Sieb. (Rhamnaceae.)

Western slope of Brisbane Ranges, South Victoria, P. R. H. St. John, September, 1911. About 3½ feet high.

In the Fragmenta, Vol. III., page 69, Mueller made this species as well as *P. lanigera*, *P. phillyroides* and five other specific names synonyms to *P. elliptica*. At the same time, however, he raised a new species, *P. grandis*, differing less from *P. elliptica* than the other species suppressed in its favour. In the last Census all the species are given as valid excepting *P. ferruginea*, thus agreeing with Bentham except on this one point. In Moore's "Flora of New South Wales" *P. ferruginea* is given as a variety of *P. elliptica*.

It seems best, however, to retain all these species, since the development of hairs upon which the distinctions between the species are largely based, though not usually reliable, seem in this case to be remarkably constant and to be associated with other characters. The villous calyx distinguishes *P. ferruginea* and *P. lanigera* from *P. elliptica*, whose leaves are white beneath, instead of more or less rusty. *P. ferruginea* has the upper surface of the leaf smooth, while in *P. lanigera* it is rough with minute white hairs.

PRASOPHYLLUM FUSCO-VIRIDE, Reader. (Orchidaceae.)

Dr. R. S. Rogers informs me that he has during the past two years examined the orchid generally known in South Australia as *P. Tepperi*, Rogers, and finds it to agree with the former species. (See also Proc. Roy. Soc. of Victoria, Vol. 22, 1909, page 19.) Only one Herbarium specimen of the true *P. Tepperi*, F. v. M., exists, and the plant may have become extinct from the single locality (Yorke's Peninsula, South Australia), whence it was recorded.

PULTENAEA WEINDORFERI, Reader. "Swamp Bushpea." (Leguminosae.)

Dandenong Ranges, Victoria, C. French, Jnr., 4/10/1911. Leaves slightly larger than in the original type specimen.

ROMULEA (TRICHONEMA) CRUCIATA, Ker-Gawl. "Onion Grass." (Irideae.)

White flowered specimen. Essendon, Victoria, C. French, Jr., 20/9/1911.

SENECIO NEBRODENSIS, L. var. GLABRATUS. (Compositae.)

Coode Island, Victoria, J. R. Tovey and C. French, Jr., October, 1908.

A native of Southern Europe and Northern Africa. This very variable plant may be regarded as an exotic not yet sufficiently established to be considered naturalised.

SENECIO PTEROPHORUS, DC. var. VERUS. "Rough Senecio." (Compositae.)

Railway Reserve, North Melbourne, J. R. Tovey and C. French, Jr., March, 1909; P. R. St. John, April, 1909.

A native of South Africa, now introduced into Victoria, but not yet sufficiently established to be considered naturalised.

STERA, Ewart. New genus. (Compositae.)

Involucres cylindrical, bracts imbricate in several rows, outer shorter and comparatively broader than inner. Receptacle very small. Florets few, 2-5 in each head, hermaphrodite or unisexual, in the latter case the florets contain abortive stamens. Florets all tubular cylindrical, with five teeth scarcely spreading, somewhat swollen towards tip when in bud. Style lobes slightly wider than style itself, about same width throughout, obtuse, slightly thickened, papillose on back. Style glabrous. Achenes from ½-2 lines long.

Pappus of numerous bristles barbed towards tip, but smooth at base, in several rows, yellowish in colour.

Shrubby plants with simple alternate, sessile leaves covered with woolly hairs. Heads solitary and terminal on short branches.

STERA CONOCEPHALA (F. v. M.), Ewart and Rees. (Compositae.)

Additional localities not given in Bentham's Flora Australiensis, 50 miles N.W. from Frazer River, West Australia, Victoria Springs; Lake Lefroy, West Australia; Murray Desert, Mallee; Murray, N.W. Bend (?)

Small branching shrub covered with grey woolly vestiture, less plentiful on older parts. Leaves crowded, small, flat, 2-4 lines long, obovate to spathulate, alternate, sessile, bearing on their outer surfaces, yellowish woolly hairs at their tips. Shape varies from oval in the basal bracts to long and elliptical in the upper inner ones.

Florets 4, extending beyond involucre. Corolla 5 lines long, cylindrical, much elongated, 5 lobes narrow and scarcely spreading, 5 stamens, abortive within tube of corolla. Style elongated and stigmas project beyond corolla. Achenes 1½-2 lines long, slender, elongated glabrous.

STERA MICROPHYLLA, Ewart and Rees. (Compositae.)

(PLUCHEA CONOCEPHALA, F. v. M., var. MICROPHYLLA.)

Lake Lefroy, West Australia.

Shrubby plant covered with vestiture of woolly brownish-grey hairs, which have disappeared from older parts. Leaves crowded, minute, about 1 line long, obovate and obtuse, covered with woolly hairs. Heads 5-6 lines long and 1½ lines broad in widest part. Bracts scaly, slightly ciliate on outer surface, linear and obtuse, increasing in length from below upwards from 3 to 6 lines.

Florets 2 in each head, extending beyond involucre. Corolla 5 lines long, narrow and cylindrical, 5 abortive stamens within tube of corolla. Style elongated, stigmas project beyond corolla. Achenes 1½ lines long, slender and glabrous. Pappus more closely barbed than in *S. conocephala*. Differs from *S. conocephala* in general appearance, size of leaves, size and shape of bracts, number of florets in head and barbs on pappus.

STERA SUBSPINESCENS, Ewart and Rees. (Compositae.)

(PLUCHEA CONOCEPHALA, F. v. M., var. SUBSPINESCENS).

Near Hunt's Well, West Australia.

Irregularly branched shrub covered with slight woolly brown vestiture, which has disappeared from older parts. Many of the lateral branches end in blunt spines. Leaves somewhat scattered, 2-4 lines long, lanceolate covered with brownish hairs. Heads terminal on short lateral branches, about 4-5 lines long and 2 lines broad.

Bracts somewhat scaly with hairs on outer surface, varying in shape and size from ovate, 1 line long on the outside, to linear about 5 lines long on the inside.

Florets hermaphrodite, 5 in each head protruding slightly beyond involucre, corolla elongated, cylindrical, 5 segments almost erect. Stamens 5, sagittate at base, connective forming blunt process above. Anthers reaching mouth of corolla tube. Achene about ½ line long, not so slender as in *S. conocephala* and *S. microphylla*. Pappus wavy at base, barbed closely at tip.

These plants were originally, but only provisionally, given under *Olearia* as *Olearia conocephala* by Bentham, and later transferred by Mueller to *Pluchea*, from which, however, it differs in several important respects. The original description is given in the Fragmenta Phytographiae Australiae, Vol. V., p. 79, as follows:—

ASTER CONOCEPHALA.

Fruticose, hairy tomentose. Leaves small, 2-4 lines long, alternate obovate to spathulate, sessile flat entire. Heads terminal solitary, few flowered, rather larger. Involucral bracts oblong, cylindrical to obconical, in several rows, imbricate, scaly, no ligules. Florets extending beyond involucre. Florets bisexual, 4-5 in head, 4 lines long. Corollas elongated, cylindrical in form, teeth erect. Achenes thin, slender glabrous. Pappus bristles becoming yellow and feathery except at base, interior longer, outer rather smaller and shorter.

Other references are to be found in the Transactions and Proceedings of the Royal Society of Victoria, Vol. 24, p. 138;

Transactions of the Victorian Institute, 1, page 36; Bentham's Flora Australiensis, Vol. III., page 480; Engler's Pflanzenfamilien, IV. Teil, 4 and 5 Abt. Mueller recognised two varieties under his "*Pluchea conocephala,*" but the first of these *(microphylla)* differs from the type in its leaves and bracts, while the second one *(subspinescens)* differs in its bracts, achenes and spinescent character.

WEHLIA, F. v. M., in Fragmenta, X., p. 22 (1876). (Myrtaceae.)

Alterations in Generic Diagnosis. Stamens 20 or indefinite. Anthers versatile or dorsifixed. Calyx tube completely or nearly hidden by the investing bracts.

WEHLIA THRYPTOMENOIDES. (Fragmenta, X., p. 22.)

Localities.—Victoria Springs, Ularing, Young, etc.

WEHLIA THRYPTOMENOIDES var. MICROPHYLLA, Ewart and Rees.

Leaves differ from the type in size ($\frac{3}{4}$ to 1 line long), and are comparatively wider.

Localities.—Lake Deborah, Hon. Sir John Forrest, 1889; Cowcowing, West Australia, Max Koch, Sept., 1904, No. 1189.

WEHLIA PEDICELLATA, Ewart and Rees, n.sp. (W. THRYPTOMENOIDES, var. PEDICELLATA).

Small shrub, somewhat similar in appearance to *W. thryptomenoides.* Branches are given off more nearly at right angles from the main stem. Leaves larger (2 to $2\frac{1}{2}$ lines long), less prominently glandular and blunt tipped. Flowers on distinct pedicels, developed in axils of leaves towards the ends of the branches. Flower differs from *W. thryptomenoides* chiefly in number of stamens (25 or rather more). Each stamen has a glandular swelling on the back between the anther lobes.

Locality.—Mount Moore, West Australia, Edwin Merrall, 1889.

Wehlia pulcherrima, Ewart and Rees, n.sp. (Myrtaceae.)

Towards Coolgardie, West Australia, W. A. Macpherson, 1895.

Branching shrub, branches somewhat elongated. Leaves 2 to 2½ lines long, linear ovate, 3 angled with bluntly-pointed tip, surface somewhat glandular. Flowers developed in axils of leaves at the ends of the branches, crowded in a head-like inflorescence. Bracts with slightly membranous edges enclosing calyx tube, which is almost or quite hidden. Surface of calyx tube slightly grooved longitudinally. Sepals 1 line long, membranous, ovoid, bluntly pointed. Petals about twice as long as sepals, ovate lanceolate, purplish in colour. Stamens 30 or indefinite, dorsifixed with gland on the dorsal surface between the anther lobes.

W. pedicellata is readily distinguished from *W. thryptomenoides* by its larger foliage, stalked flowers and more numerous stamens. *W. pulcherrima* is distinguished from the preceding by its still more numerous stamens (30 or more), terminal clustered inflorescence and larger flowers. Two other species have been described by Baron von Mueller from West Australia, *W. staminosa* (Wings Southern Science Record, III., 1884, p. 282), and *W. coarctata* (Fragmenta, X., p. 23, 1876). The former has a larger number of stamens (up to about 40) than any other species; *W. coarctata* has the leaves neither angular nor pointed, the pedicels longer than the calyx and the stamens as in *W. thryptomenoides*. The leaves readily distinguish it from *W. pedicellata*, which has also pedicels longer than the calyx.

EXPLANATION OF PLATES.

Plate LII.

Capparis umbonata (Figs. 1-2), *Erythrostachys prolifera.*

Fig. 1.—Fruit of *Capparis umbonata.*

2.—The same in transverse section—(a) seed, (b) seed cavity in fruit, (c) fibrous woody pulp.

3-7.—*Erythrostachys prolifera* (T. Ag.). J. White.

Fig. 3.—Frond of *Erythrostachys prolifera* (natural size).
4.—Tertiary branch (highly magnified).
5.—Small portion of transverse section of the main axis (magnified).
6.—Small portion of transverse section of the central part of the main axis (highly magnified), (e) cells filled with vacuolar physodes.
7.—Small portion of longitudinal section of the main axis (magnified).

Plate LIII.

Hymenophyllum peltatum (Poir), Desv.

Fig. 1.—a. Frond of *Hymenophyllum peltatum.*
b. Sorus of same.
c. Sporangium of same.
2.—a. Frond of *H. multifidum.*
b. Sorus of same.
c. Sporangium of same.
3.—a. Frond of *H. tunbridgense.*
b. Sorus of same.
c. Sporangium of same.

Plate LIV.

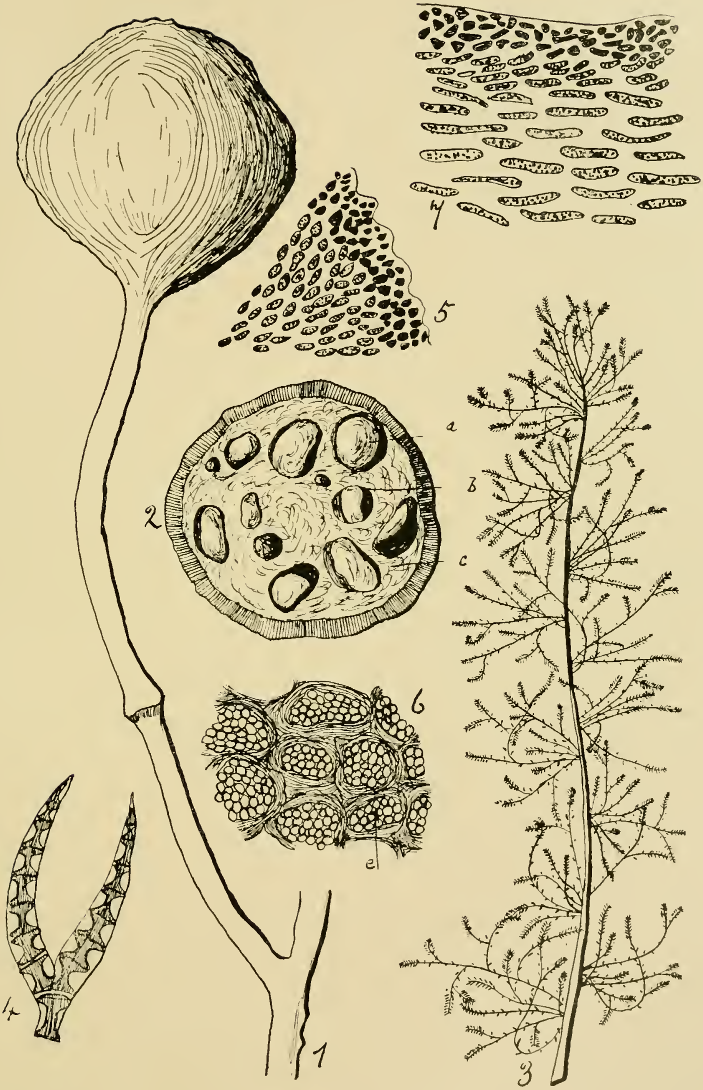
Pimelea Treyvaudi, (F. v. M.) Ewart and Rees.

Fig. a.—Portion of plant of *P Treyvaudi.*
b.—Bract (much enlarged).
c.—Flower (enlarged).
d.—Flower opened up to show attachment of stamens and the gynaecium.

Plate LV.

Stera, Ewart.

Fig. a.—Portion of *Stera conocephala*, Ewart and Rees (natural size).
b.—Portion of *Stera microphylla*, Ewart and Rees.
c.—Portion of *Stera subspinescens*, Ewart and Rees.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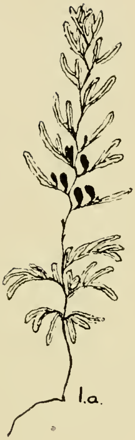
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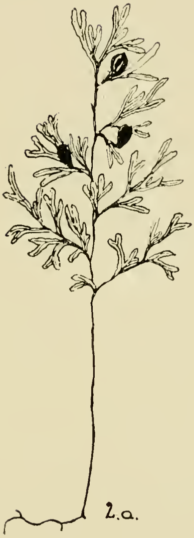
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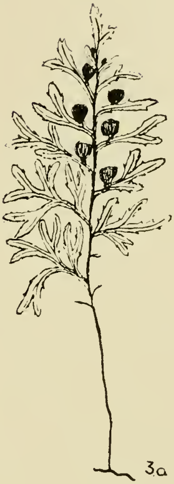
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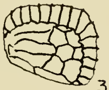
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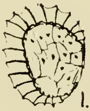
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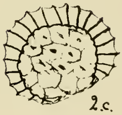
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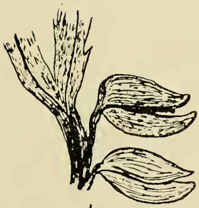
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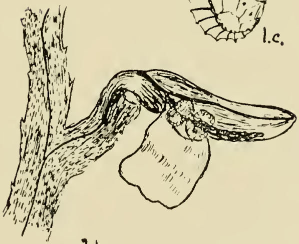
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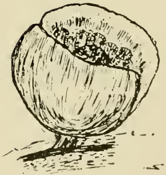
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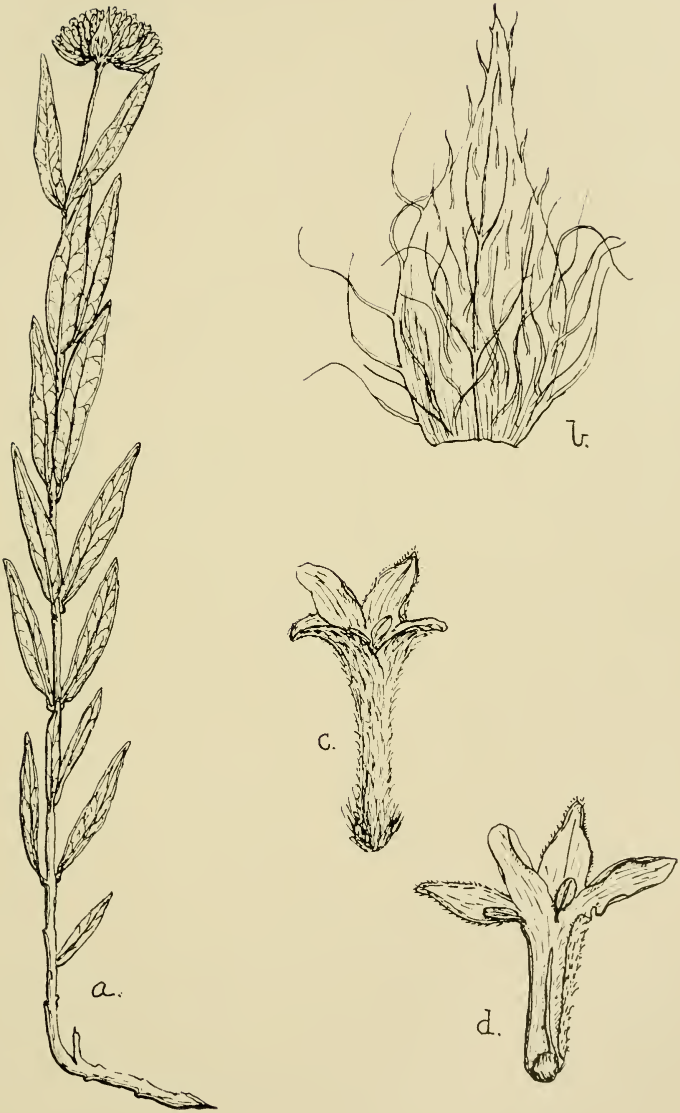
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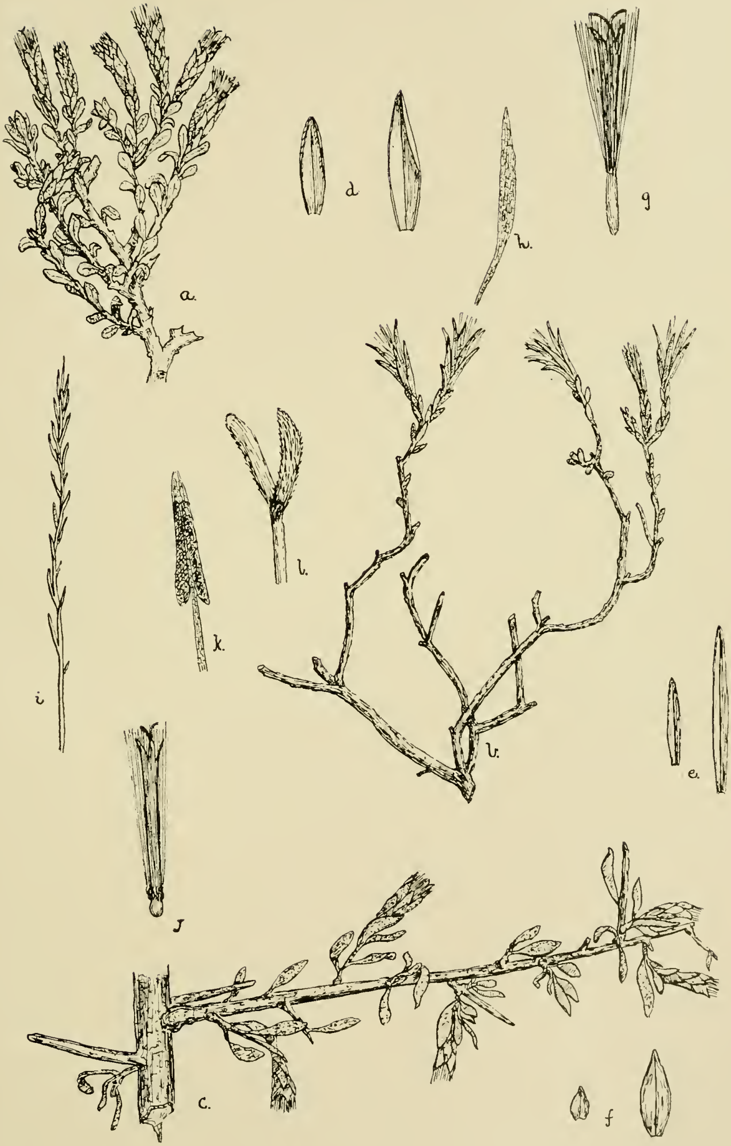
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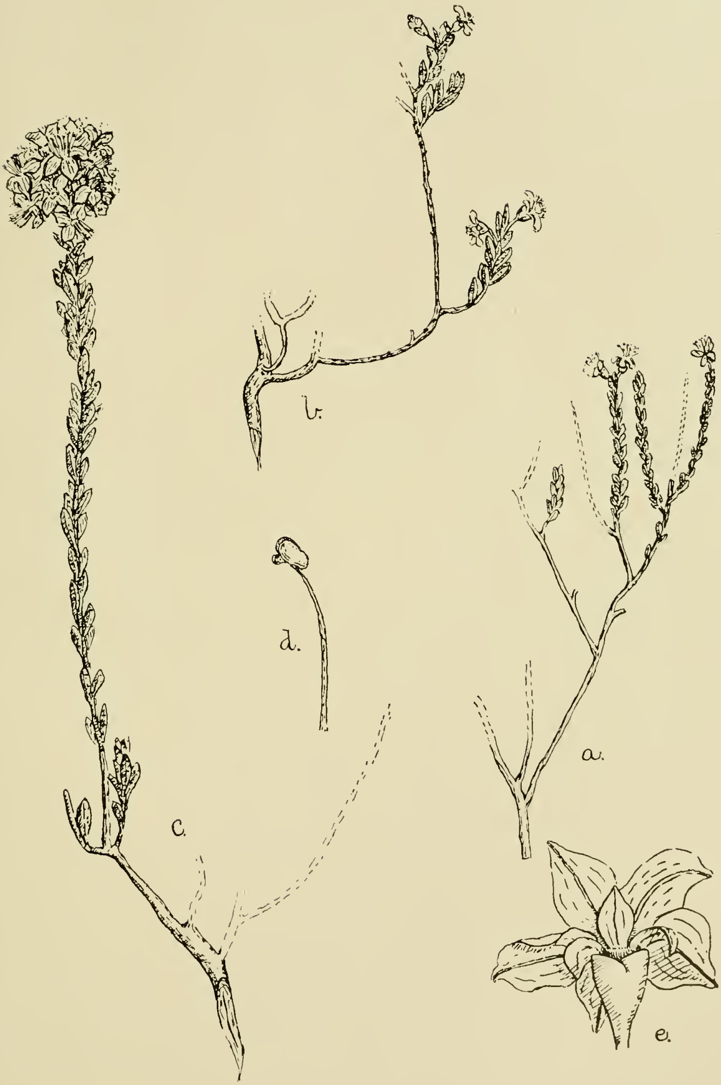
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Fig. d.—Bracts of (a) (extremes of size and shape) × 2.
e.—Bracts of (b) (extremes of size and shape) × 2.
f.—Bracts of (c) (extremes of size and shape), × 2.
g.—Typical floret of (a) and (b) × 3.
h.—Staminode of (a) and (b) (low power).
i.—Bristle of Pappus, × 7.
j.—Floret of (c) × 3.
k.—Stamen of (c) (low power).
l.—Stigma (typical), (low power).

PLATE LVI.

Wehlia.

Fig. a.—Portion of plant of *W. thryptomenoides.*
b.—Portion of plant of *W. pedicellata.*
c.—Portion of plant of *W. pulcherrima.*
d.—Typical stamen of *Wehlia.*
e.—Single flower of *W. pulcherrima* (back view).

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XX.—*The Effect of Certain Chemical Substances on the Vitality of the Buds of Potato-Tubers, and their Disinfective Action on Potato Blight (Phytophthora infestans).*

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(Government Botanist, Western Australia).

(Communicated by Alfred J. Ewart, D.Sc., Ph.D., F.L.S.)

(With Plates LVII.-LX.).

[Read 2nd November, 1911.]

The treatment of potatoes, destined to serve as seed tubers, by immersion in aqueous solutions of various antiseptic reagents, as a preventive means against certain disease-producing organisms, chiefly parasitic fungi, is a practice which is gradually becoming more and more general.

The basis of the practice, at least in the hands of the majority of potato growers, is largely if not completely empirical. The criteria usually relied upon as to the effectiveness or success of this or that method of treatment against potato diseases and their dissemination, are essentially based on the crop-yield, and its comparative freedom from the disease which the treatment is tentatively designed to lessen or even eliminate.

Although broadly recognised as essentially antiseptic, or under certain conditions toxic in their action, little attention appears to have been devoted to the study of either the mode of action on, or the possible penetration of these reagents into, the tissue of the tuber: whether, for example, penetration of these chemical substances does or does not take place, and if the former alternative holds, whether penetration occurs exclusively through the skin, or through both buds and skin; or whether under certain conditions their action, though at first it may be effective and beneficial, becomes decidedly harmful, etc.

At the outset it is desirable to state that the original objective sought in this inquiry, namely, the evolution and application of a method of treatment which, while effectively annihilating the sprouting power of the treated tuber, and, in the case of blight-infected material, also that of the causal fungus (*Phytophthora infestans*, De Bary), yet would not greatly impair its storage, culinary and edible qualities, has to some extent undergone deviation.

The present brief paper is merely a resumé of certain experimental work performed, and the results which it has so far furnished. While the work recorded lacks that completeness in certain directions which must naturally accrue from a more detailed investigation, it has nevertheless been deemed advisable to record such definite stages as the inquiry has so far reached.

Briefly set out, the principal objects of the inquiry have been to ascertain the influence exercised under definite conditions of time, temperature and concentration, by certain antiseptic compounds of definite chemical composition, in aqueous solution, on blight-free or blight-infected tubers, particularly in regard to the annihilation of the buds, of the treated tuber, and in the case of blight-infected material, of the hibernating mycelium of the blight-causing fungus (*Phytophthora infestans*).

Material and Experimental Method.

Certain distinct types of Victorian tubers, specifically denoted in the text as thick or thin-skinned, and varying in their degree of maturity, served as experimental material. The earlier series of experiments refer exclusively to blight-free tubers, which were steeped in brine solutions of varying strengths. Following on these are experiments with similar blight-free material, steeped in aqueous sulphuric and boracic acid solutions. Succeeding these are the experimental results furnished by steeping material in other antiseptic steep solutions, and lastly are experimental results afforded by the treatment of blight-infected material in like solutions.

The method of experiment adopted has been to steep a definite number of tubers at the temperature of the laboratory (16° – 18° C) in aqueous solution of the different chemical substances enumerated, for definite time periods; at the termination of each steeping experiment to wash the treated material, and then to divide it into separate lots, one of which was placed under ordinary dry storage conditions, a second planted in good garden soil, a third cooked immediately after treatment, and the residue of this last lot at a later interval. In the case of blight-infected material, these subsequent investigations were subjected to planting, cooking, storage, and also to "forcing" tests, in which the treated material was placed under optimal conditions of temperature and moisture for the rapid development of the hibernating blight-fungus.

Preparation of Steep Solutions.

Ordinary unpurified table salt (NaCl) was dissolved in tap water, and solutions of approximately 5 per cent., 10 per cent. brines, etc., were prepared. Aqueous solutions of sulphuric acid, boracic acid, phenol, formaldehyde, etc., of approximately the strengths indicated later on were similarly prepared, with ordinary commercial samples of each of these different reagents. The experiments were established by placing the tubers in tall glass cylinders, and pouring in a sufficient bulk of solution until the material was just completely covered. As no effective means of readily checking evaporation at the surface of the solution were available during the course of these experiments, and moreover as it is a difficulty which would present itself in actual practice in other than laboratory experiments, no attempt was made to control this factor.

Experimental Data. Brine Steeps.

(a) Blight-free peeled tubers, Victorian mature thick-skins. Entry of the solution into the storage tissue of tubers.

The lots of peeled tubers (5 each) were steeped in brines of 4.2 per cent., 9.32 per cent., and 17.91 per cent., strengths for five days (4.2 per cent.) and six days (9.32 per cent. and 17.91 per cent.). Specimens of the brine were removed at intervals, conveniently diluted to definite volumes, and estimations of their respective chloride contents carried out.

In the table beneath are given the amounts of chlorides per 100 c.c. of brine solution at 5 and 6 days.

Table 1.

Grams chlorides expressed as NaCl per 100 c.c. soln.

At commencement	4.27	9.32	17.91
After 5 days ...	3.77	6.58	11.93
After 6 days ...	—	6.58	11.84
Percentage of salt withdrawn from 100 c.c. of solution, after 5 days	20.02	29.45	33.39
do. do. 6 days ...	—	33.24	33.89

As these quantitative data show, a considerable amount of salt passes by diffusion from the solution into the tissue of the peeled tuber. The titre of the external solution undergoes a gradual fall. This fall, probably rapid at first, gradually slows down, until at about five or six days a condition of equilibrium is attained. The principal feature of these experiments to be noted is the rapidity and order of magnitude of the process of diffusion which occurs in the case of the peeled tuber, a phenomenon which is, as we shall see, chiefly caused by the removal of the skin of the steeped object.

The above results do not give an entirely accurate measure of the passage of the solute from the solution into the tissue of the tuber, for during the course of these and similar experiments, evaporation of water occurs at the surface of the salt solution, and this tends to concentrate it. The values given above (and those in the succeeding tables) actually measure the resultant of two opposed processes, diffusion of salt from the solution into the tuber, and evaporation of water from the solution, processes which respectively tend to diminish and increase its concentration.

These data, however, sufficiently demonstrate (under the selected conditions of experiment), that common salt (NaCl) very freely diffuses into and is absorbed by the tissue of peeled tubers.

Direct estimations of the chloride content of the tissue of treated and untreated tubers definitely show that after treatment considerable amounts of salt are absorbed, and moreover afford a more accurate measure of the order of magnitude of this process.

In these and similar determinations, the material, after desiccation at 105° C to 107° C, until its weight was approximately constant, was carefully and completely carbonised at a low red-heat, then repeatedly extracted with hot water; the aqueous extracts were filtered, and filtrate and washings, after cooling, were made up to a definite volume. Titrations of definite volumes of the filtrate were then carried out. The values calculated from these data are summarised in the table beneath.

TABLE 1A.

Percentages of moisture and chlorides calculated on air-dried tissue.

	Moisture	Chlorides (calculated as NaCl)	Approximate relative increase in salt content NaCl)
Peeled tubers (untreated)	70.2	0.28	1
Peeled tubers after 6 days steeping in 10 per cent. brine	66.9	2.29	10
Peeled tubers after 6 days steeping in 20 per cent. brine	65.86	4.96	20

The tubers after treatment were found to have completely lost their originally solid texture, and to possess a rubber-like elasticity, a condition induced by the extensive plasmolysis of the more peripherally situated portions of the storage tissue.

It is of interest to note the occurrence, at a comparatively early stage in these steeping experiments, and notably in the weakest concentration of brine (5 per cent.), of marked bacterial development and activity. Thus in this instance the onset and rapid progress of the phenomenon even under the temperature conditions stated, render it necessary to terminate this experiment on the fifth day. In every instance bacterial growth was chiefly confined to the external solution, and the motile types present were those usually associated with starch degradation.

It is probable that extraction of certain proteins and their derivatives occurs more rapidly with a 5 per cent. brine than with the higher concentrations, although the possible inhibitive effect of these higher concentrations on bacterial activity is not excluded. The point is one for future investigation, and requires controlling by Kjeldahl nitrogen estimations, and the institution of "salting out" experiments. The fact remains that toward the third to sixth day the steep-solution becomes a veritable culture medium.

These suggestions regarding the manner in which brine functions are supported by the fact that in parallel experiments in which like material was steeped in plain water, bacterial development was not so advanced, as shown by both microscopical and macroscopical observation.

Blight-free Unpeeled Tubers.

The experimental results so far related indicate that when peeled tubers are steeped in brine solutions, salt penetrates rapidly and freely into the tissue, and plasmolysis and ultimately death of the cellular units take place.

It remained to endeavour to ascertain whether entry of salt takes place so freely when intact, unpeeled tubers are steeped in brine solutions.

In the table hereunder and those which follow, the summarised experimental data are typical of and selected from a mass of similar essays, in which three different types of tubers—

(1) mature thick-skinned Victorian tubers,
(2) less mature thin-skinned Victorian tubers,
(3) less mature thin-skinned Victorian tubers,

served as the experimental material.

At the outset it may be stated that non-removal of the skin of the tuber prior to steeping, effectively retards the entry of the solute. This fact is well shown by the results of the following typical experiment.

Experiment:—Two lots (5 each) mature thick-skinned Victorian tubers, steeped in brines (a) and (b) for ten days. First determinations of chloride content of brines made after three days' steeping and subsequently after 4, 8 and 10 days.

TABLE 2.

Grams chlorides (calculated as NaCl) per 100 c.c. of solution.

At commencement	(a)	-	(b)
After 3 days' steeping	8.35	-	9.21
After 4 days' steeping	8.41	-	9.27
After 8 days' steeping	8.50	-	9.30
After 10 days' steeping ...	8.47	-	9.24

Estimations of the moisture and chloride content made on this material yielded the following data:—

TABLE 2A.

Percentage of moisture and chlorides calculated on air-dried tissue.

	Moisture		Chlorides (calculated asNaCl)		Approximate relative increase in salt content
Intact tubers (untreated)	70.02	-	0.28	-	1
Do. after 10 days (a)	72.3	-	0.69	-	2
Steeping ... (b)	73.4	-	0.66	-	2

Additional experiments were then instituted, in order to follow more closely the behaviour of intact tubers, differing in type and degree of maturity, on steeping in brine solutions of different concentration, to accumulate data similar to those already amassed, and to extend the investigations along lines which might have certain practical applications.

Experiment:—Two lots (5 each) mature thick-skinned Victorian tubers, separately steeped in 10 per cent. and 15 per cent. brines for eight days.

TABLE 3.

Grams chlorides calculated as NaCl per 100 c.c. of solution.

	10 per cent.		15 per cent.
At commencement	9.65	-	14.53
After two days	9.71	-	14.43
After five days	9.83	-	14.46
After eight days	9.69	-	14.19

TABLE 3A.

Percentages of moisture and chlorides calculated on air-dried tissue.

	Moisture	Chlorides (calculated as NaCl)	Approximate relative increase in salt content
Intact tubers (untreated) ...	69.98	0.28	1
Intact tubers after 10 days' steeping, 10 per cent. ...	—	0.25	1
Intact tubers after 10 days' steeping, 15 per cent. ...	—	0.54	2

Experiment:—Two lots (5 each) less mature thin-skinned South Australian tubers, steeped in 15 per cent. brine for 11 days.

TABLE 4.

Grams chlorides calculated as NaCl per 100 c.c. of solution.

	(a)	(b)
At commencement	14.52	15.05
After 11 days' steep ...	14.22	15.17

Experiment:—Two lots (5 each) less mature thin-skinned Victorian tubers, separately steeped in 10 per cent. and 15 per cent. brines.

TABLE 4A.

	10 per cent.	15 per cent.
At commencement	9.69	14.19
After 8 days' steep	9.48	13.86

TABLE 4B.

Percentages of moisture and chlorides calculated on air-dried tissue.

	Moisture	Chlorides
South Australian tubers ...	70.67	0.66
Victorian tubers	70.60	0.89

These results justify the statement that, in contradistinction to peeled tubers, with unpeeled tubers, after long steeping in 10 per cent. or 15 per cent. brines, the amount of salt which diffuses from solution into the tuber is of a relatively small order of magnitude.

Since the behaviour of the unpeeled differs so distinctly from that of the peeled tuber, in regard to the entry of salt into its tissues, it is difficult to avoid the conclusion that the intact skin presents a barrier to the ready entry of the dissolved substance. As it is difficult to devise any satisfactory colorimetric method for demonstrating the presence of the small quantities of the chloride in the tissue, and of thus localising its points of entry, the further discussion of this aspect of the question may well be deferred until certain crucial experiments with tubers steeped in sulphuric acid are described and considered.

The brines in these experiments remained perfectly clear, and slight bacterial development only took place, demonstrating that practically little, if any, nutrient substances were extracted from the steeped objects.

Storage and cooking tests were most unsatisfactory. The stored tubers rapidly softened, lost weight, discoloured and finally decayed.

Specimens from each of the series were planted in good garden soil, and there remained for eight weeks. In every instance the results were negative, conclusively showing that the vitality of the dormant buds of the treated had been destroyed by the treatment.

Specimens of these brine-steeped peeled and unpeeled tubers, immediately after treatment, were cut in halves, and the cut surfaces freely exposed to the air. After 24 hours' exposure, the superficial tissue to a depth of several millimetres invariably acquired a greyish-black to black colour.

That this phenomenon is enzymatic in its nature is shown to be highly probable by the following experiments and observations.

Untreated tubers (A) and brine-steeped tubers (B) were bisected and exposed for 24 hours. Both series exhibited the progressive darkening of their exposed sectioned surfaces. After an hour's exposure a pinkish coloration commenced at the margin, later a liver-coloured tint, and still later a greyish black, and finally after the lapse of 24 hours a black coloration, the intensity and rapidity of the changes being more marked in series B.

The phenomenon is superficial, and its progress is governed by gradual desiccation of the surface tissue, and also probably by comparative lack of free oxygen in the subjacent tissue.

The superficial layers to a depth of a few millimetres were removed, and thin slices of the subjacent tissue in each series were prepared. These were divided into two lots, one of which was placed in water and heated nearly to boiling point and maintained at this temperature for some minutes. The boiled and unboiled sections were then exposed in a moist space, under otherwise parallel conditions: after the lapse of 24 hours the following observations were made:—

Boiled	Unboiled	Boiled	Unboiled
No visible color change	Intense coloration	No visible color change	Very intense blackening

The phenomenon is probably due to the action of the oxidising enzyme tyrosinase on the protein dissociation product tyrosin. The occurrence of tyrosin in potatoes has been definitely established by Studel[1], and by Schulze and Winterstein[2].

The more intense darkening invariably observed in series B and similarly treated material is probably due to the partial disorganisation and death of the cellular units, and the consequent freer diffusion of either the enzyme or tyrosin or both, from cell to cell.

Blight-free Intact Tubers. Sulphuric Acid Steeps.

The outstanding fact furnished by the foregoing experiments, viz., that even on prolonged steeping in brines ranging from 10 per cent. to 20 per cent. strength, the dissolved substance only entered the steeped unpeeled tuber in small amount, led to the institution of experiments with aqueous solutions of sulphuric acid. In each of the experiments summarised in the tables beneath, five tubers were selected and separately steeped in a 5 per cent. or 10 per cent. solution of sulphuric acid, for the time periods indicated, and at laboratory temperature, 16° - 18°Co.

At the termination of each experiment the material was removed, washed, divided into two lots of three and two tubers each, the former planted in good garden soil (vitality test) and the latter stored in paper bags (storage test).

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[1] Deutsche med. Woch. 1900, p. 273.

[2] Zeitschr. f. physiol. Chem. 35, 299, (1902) and 45, 79, (1905).

The immediate objects of these experiments were :—

(1) To establish as definitely as possible whether or not the vitality of the buds, and hence the sprouting power, was destroyed ; and

(2) To test whether or not the storage qualities of the different types of tubers were impaired, under the selected conditions of treatment.

Table 1.

Results of planting and storage of acid-treated tubers.

A.—Mature Victorian thick-skins.

5 per cent sulphuric acid.

Expt.	Date of treatment	Duration of steeping	Date of planting	Behaviour on		Keeping quality of stored tubers
				(a) planting	(b) storage	
1	10/7/11	2 hours	10/7/11	3 growing	2 sprouted	good
2	10/7/11	6 ,,	10/7/11	0 ,,	2 ,,	,,
3	12/7/11	3 ,,	12/7/11	2 ,,	2 ,,	,,
4	12/7/11	1 ,,	12/7/11	3 ,,	2 ,,	,,
			10% sulphuric acid.			
5	13/7/11	5 hours	20/7/11	1 growing	0 sprouted	good
6	13/7/11	1 ,,	20/7/11	3 ,,	2 ,,	,,
7	19/7/11	20 ,,	20/7/11	0 ,,	0 ,,	,,
7a	17/7/11	3 ,,	20/7/11	0 ,,	0 ,,	,,
7b	17/7/11	2 ,,	20/7/11	0 ,,	1 ,,	,,

B.—Mature Victorian thin red-skins.

8	19/7/11	4½ hours	20/7/11	1 growing	0 sprouted	good
9	20/7/11	2½ ,,	20/7/11	1 ,,	1 ,,	,,

C.—Mature South Australian thin-skins.

10	18/7/11	3 hours	20/7/11	0 growing	2 sprouted	good
11	18/7/11	5 ,,	20/7/11	1 ,,	0 ,,	,,

These observations were made on August 24, 1911, and again on August 28, 1911; on the latter date the accompanying photographs were taken of the planting and storage test experiments.

Immersion for from three to six hours in either 5 per cent. or 10 per cent. sulphuric acid induces marked retardation of growth. In certain cases (Experiments 2, 7, 7a, 7b, 10) actual suppression of the sprouting powers of the tubers resulted. These results, although variable, are not surprising, when the variability of the material, and the possible individuality possessed by such biological material, are given due consideration.

The effect of the 10 per cent. solution is in no way doubtful; a steep in this concentration of acid, of 20 hours' duration, effectively and conclusively destroys the vitality of the buds of the treated tubers.

In addition to the numerical data in the above tables the accompanying Plates LVII., LVIII., LIX. (planting and storage experiments) indicate both the retardation and the destructive influence exercised by sulphuric acid when used as a steeping reagent. The storage quality of these tubers was in every instance unimpaired. In the above experiments, after two months' storage, it was impossible to differentiate them from the untreated but otherwise similar tubers, which served as a control in these storage tests.

In experiments 7, 8 and 11, the amount of acid in definite volumes (100 c.c.) of solution was determined at the commencement and termination of the experiments; these results are given below:—

Expt.	Grams of acid per 100 c.c. of solution		Decrease in amounts of acid per 100 cc. of solution.
	At commencement of steeping	At termination of steeping	
7	9.408	9.359	0.049 grams.
8	9.408	9.408	0.00 grams.
9	9.506	9.408	0.098 grams.

It is evident that the amounts of acid which diffuse from the steeping medium into the tubers are relatively minute.

Since in each of these experiments 1.500 c.c. of acid solution were used, and the average weight of (1) 5 tubers was approximately 1.650 grams, all the necessary data are available for calculating the apparent percentage weight of acid absorbed.

Taking for example experiment 9, we have weight of acid withdrawn from 1.500 c.c. = 15 × 0.098 grams.

Percentage of acid apparently present in tubers

$$= \frac{15 \times 0.098 \times 100}{1650} = 0.089 \text{ per cent.}$$

As we shall shortly see, the distribution of the acid absorbed is not uniform, but localised in the buds and the immediately subjacent tissue.

Again it is probably more correct to state that the evaluation of the percentage of acid absorbed is too high, for the fall in the titre of the solution is partly accounted for by the adherence of the acid to the skin of the treated tuber.

So far no definite evidence has been adduced as to the localisation of the points of entry of the dissolved substances into steeped tubers.

As we have seen the amounts of sodium chloride and sulphuric acid which diffuse into the steeped tuber are relatively small, and while ordinary quantitive chemical determinations indicate with tolerable precision the general trend of the diffusion processes, these suggest rather than definitely establish the fact that absorption of the solute is exclusively confined to the buds.

The entry of sulphuric acid into the mature blight-free and undamaged tubers, it may be stated, takes place exclusively through the buds.

The point is capable of precise demonstration: the freshly-cut tuber, whether untreated or after steeping in water, on testing with an aqueous solution of methyl orange, gives a distinctly alkaline reaction. It follows, therefore, if, after steeping tubers in an aqueous solution of H_2SO_4 deeply coloured with methyl orange, for five or more hours, and then carefully washing with distilled water to remove the last traces of acid adherent to the surface, a persistent pink colour is demonstrable at any point beneath the skin, that both acid and indicator have been absorbed. If, for example, an intact tuber, the skin of which is undamaged, is thus treated, and sectioned so that the plane of section includes a bud or "eye," it will be found that the bud and the immediately subjacent tissue for the depth of a few millimetres, is more or less distinctly mapped out by a pink coloration, which is intense superficially, and becomes gradually fainter as it is traced internally. That methyl orange alone does not give this colour reaction may easily be controlled by steeping similar tubers in an aqueous solution of the indicator containing approximately the same concentration of methyl orange as the acid solution.

These facts therefore justify the conclusion that the entry by diffusion of the dissolved substance so far tried is exclusively *via* the buds or " eyes " of intact mature tubers.

The point demonstrated is, as we shall shortly see, of importance when we come to deal with the behaviour of blight-infected tubers on exposure to the action of aqueous sulphuric acid.

Plate LX. shows the appearances presented by such a tuber as that described above, after 20 hours' steeping in 10 per cent. aqueous sulphuric acid plus methyl orange.

Blight-free Intact Tubers. Boracic Acid Steeps.

The steeping of intact tubers in solutions of common salt and sulphuric acid, as we have seen, is attended by very restricted diffusion of these reagents through the skins of the steeped tubers. It was of interest to investigate in this particular respect the action of boracic acid.

This acid has a much lower solubility than either of the reagents mentioned, functions as a comparatively mild antispetic, and in aqueous solution possesses certain physicochemical properties which differentiate it from both NaCl and H_2SO_4.

The following experiment may be taken as typical of the results furnished by steeping intact tubers in aqueous solutions containing 1.61 per cent. and 0.63 of the acid.

Experiment:—Two lots (5 each) thick-skinned Victorian tubers were separately steeped in (1) 1.61 per cent. and (2) 0.63 per cent. boracic acid solutions for 10 and 11 days respectively, and the titres of the solution determined at the commencement and termination of the steep experiments.

	Grams boracic acid per 100 cc. of solution. (1)		(2)
At commencement	1.61	-	0.63
At termination	1.60	-	0.65

The results are, as regards the comparative non-diffusibility of the dissolved substances through the skin or rind of the tuber, quite comparable with those derived from otherwise parallel experiments save that NaCl or H_2SO_4 was displaced by boracic acid.

It may be definitely stated that boracic acid like NaCl and H_2SO_4 in aqueous solution, under the conditions of experiment indicated, does not diffuse through the skin of the tuber.

The usual planting, storage and cooking tests were carried out with this material; no signs of growth were apparent, even after a lapse of two months, thus showing that the treatment had effectively extinguished any residual vitality the buds of the treated tubers may have possessed prior to the institution of the planting tests. The storage and cooking tests were quite satisfactory, the treated tubers retaining their normal solidity, cooking well, and being quite wholesome.

A small parcel of tubers immersed in a 2 per cent. boracic acid solution, contained in tins which prior to shipment were hermetically sealed, were sent from Melbourne to Perth. These arrived in good order, little or no bacterial activity was evident in the solutions, and the tubers on opening the tins were found to be quite sound and solid. After exposure, however, parts of the surface of each tuber became much discoloured, and in these superficial areas bacterial decay set in and rapidly progressed.

It is highly probable that during transit the tubers were unavoidably bruised at the parts of their surfaces at which, after removal from the solution, discoloration and eventually decay of the subjacent tissue took place. As possible injury by bruising during the laboratory operations was both controllable and avoidable, the tubers in my experiments did not exhibit these degenerative changes.

It is interesting to note that in these experiments with boracic acid as the steep-medium little or no bacterial development was apparent.

The results afforded by the foregoing experimental data justify the following conclusions:—

(1) When mature blight-free tubers are steeped in aqueous solutions of either common salt, sulphuric or boracic acid, under

the conditions of time, temperature and concentration of salt or acid stated, only minute amounts of the dissolved substance diffuse into and are absorbed by the steeped tubers.

(2) If the skins of mature intact tubers are undamaged, the entry of sulphuric acid takes place exclusively via the buds or "eyes" of the tubers, and the same statement applies, at least during the earlier phases of the steep experiment, in reference to the entry of NaCl and H_3BO_3.

(3) If the steeping in sulphuric acid is restricted within certain limits of time and concentration of acid, the vitality of the buds or "eyes" of the tubers is unimpaired or not greatly impaired. If these limits are exceeded, the vitality of the buds is effectively destroyed, without, however, seriously damaging either the cooking and edible or storage qualities of the treated tubers provided that the period of storage is not inordinately prolonged, and dry and airy storage conditions are maintained.

Blight Infested Intact Tubers. Steeps in Aqueous Solutions of Various Reagents.

The stages of the enquiry so far related refer exclusively to the treatment of blight-free tubers, the entry, mode of entry, and action on the vitality of the buds of the treated tubers of certain chemical substances, under controllable conditions of experiment. The accumulation of convincing and definite evidence on these points, and the possible practical application of the knowledge acquired, rendered it desirable to extend the inquiry to the investigation of blight-infected material.

It became, for example, a matter of special interest to investigate the possible influence one or other of the methods of treatment essayed might exercise on the vitality of the hibernating mycelium of the blight-inducing fungus, which, it is very generally accepted, resides in the infected tuber; this latter being regarded as the chief vehicle of dissemination of this difficultly combatable disease from district to district, it may be from country to country.

The question may assume a form which is not devoid of economic importance. In certain circumstances it may be desirable and justifiable for a State to close its ports and markets against the importation of tubers from another State, in which the crops furnishing the main source of seed-supply have, it may be very recently, been badly invaded by Irish Blight. On the one hand absolute prohibition of a particular foodstuff is a difficult and grave matter; on the other the introduction of disease-carrying seed tubers constitutes a grave menace to the local industry, especially if no previous and authentic history of its appearance exists, or if such has been authentically recorded, no recrudescence of the disease has manifested itself after the lapse of a period of time which may reasonably be supposed to have been ample for its complete disappearance.

It follows that if a means could be devised, at once not too costly or difficult of execution, whereby bright-infected tubers could be subjected to treatment which, while rendering them useless for seed purposes, would not impair their use for human consumption, then the dual menace suggested might effectively be surmounted.

The importation of blight-carrying tubers might then be permitted without risk of introducing or re-introducing diseased material, and moreover its subsequent dissemination by planting affected tubers might be practically if not completely eliminated.

As we have seen, although prolonged steeping of blight-free tubers in aqueous solutions of sulphuric acid under certain definite conditions results in (1) the complete destruction of the sprouting power of the tuber, and thus renders it useless for seed, it does not (2) seriously impair either its keeping or culinary qualities. The experimental work briefly described in the present section relates exclusively to the steeping of blight-infected material, of which various lots, differing in type of potato and degree of infection, were obtained and subjected to treatment on both a laboratory and a larger scale.

An illustrative example will suffice. Six lots (15-20 each) of tubers were separately steeped for ten days as under:—

Experiments 1, 2, 3, 4, 5, 6 in solutions indicated in the following table.

Experiments 7 and 8—unsteeped controls.

After four days' immersion, specimens (five tubers in each instance) were removed from experiments 1, 2, 3 and 6, and separately "forced"—i.e., placed under favourable conditions of temperature (65° to 70°F.), and humidity for the development of the causal fungus and its characteristic fructifications.

It is to be noted that in all these forcing tests the necessary safeguards against possible cross-infection were taken.

After ten days' immersion a second series of forcing tests was instituted, ten tubers from each experiment being separately forced, and subsequently investigated after expiration of 12, 24 and 28 hours. Included in this second series of tests were two untreated lots of tubers which served as controls. Of these one (a) was drawn from the same bulk as experiments 1-6, while (b) was derived from another source. The chief object aimed at in duplicating these control-forcing tests was to demonstrate beyond all reasonable doubt that the condition of experiment under which the "forcing" tests were carried out was such as to induce the active development of the hibernating mycelium which a previous trial of like material had also shown to be present.

The forced material was subjected to searching microscopical examination, and the results are briefly synopsised in the table beneath. Where obvious and undeniable evidence of the development of the blight fungus was demonstrable (experiments 7 and 8) is indicated by a plus (+) sign, where no sign of its presence was detected (experiments 1-6) a negative sign (–) signalises the fact.

Expt.	Treatment Material steeped in	Results of forcing tests 4 days	 10 days
1	0.25 per cent. phenol solution	–	–
2	0.25 per cent. formalin solution	–	–
3	1.0 per cent. boracic acid ...	–	–
4	4.0 per cent. boracic acid ...	–	–
5	15 per cent. NaCl 1 per cent. bor. acid solution	–	–
6	Plain tap water	–	–
7	Control a	–	+
8	Control b	–	+

The evidence derived from these experiments indicates that when mature blight-infected tubers are steeped under the above conditions, examination of the material at four or ten days fails to reveal its presence. The evidence was just as conclusively negative in experiments 1-6 as it was positive in experiments 7 and 8, and it is difficult to interpret the results other than by stating that as the result of steeping infected tubers in both solutions (experiments 1-5), or in plain water (experiment 6) the hibernating mycelium of the fungus is completely suppressed. In the latter, it is not improbable, considering the marked aerobism of the fungi in general, that the effect is induced by asphyxiation through prolonged drowning.

Planting tests carried out with portions of the material from experiments 1 to 5, were entirely negative, while the material from experiment 6 underwent advanced decay, during the process of steeping.

Subsequent work in this direction was confined to steeping blight-infected material in aqueous solutions of 2.5, 5.0, or 10 per cent. strengths, for a uniform period of steeping of 16, and finally of 10 hours' duration. Different kinds of tubers varying considerably in degree and extent of infection, were used, and the magnitude of these latter experiments emerged from a laboratory to a practical scale, a sack (1½ cwt.) of tubers being steeped in each of these essays. The customary "forcing," storage and cooking tests were carried out in each of these experiments.

While a steep of 10 hours' duration in a 2.5 or 5.0 acid generally proved inadequate to suppress the vitality of buds and fungus, the results of steeping material for the same period in 10 per cent. acid were invariably negative, i.e., no development or growth of either buds or fungus ensued. The most careful microscopical examination failed to reveal the presence of the fungus; contemporaneous "forced" controls invariably gave positive results.

These results justify the conclusion that when blight-infected mature tubers are steeped in 10 per cent. aqueous sulphuric acid for 10 hours, the sprouting power of the steeped tuber and the hibernating mycelia of the blight fungus were completely destroyed.

Critical storage and cooking tests show that the tissue of these tubers undergoes only slight and tardy deterioration provided that these are only slightly infested with blight. Where extensive areas of the skin are involved, their storage quality is plainly defective and unsatisfactory. This statement equally applies even in the case of untreated tubers and particularly so under unfavourable conditions of storage.

It remained to subject blighted tubers to the test with 10 per cent. sulphuric plus methyl orange. Badly blighted specimens were steeped for varying periods—5, 10 and 20 hours, and sections of these tubers were prepared similarly to those earlier described. These when submitted to both macroscopical and microscopical examination, showed that wherever the skin was overlying tissue which had been invaded by the blight fungus, there the acid and indicator had freely entered and diffused into the subjacent tissue. Entry of the acid, therefore, is not exclusively confined (as in blight-free tubers) to the buds. In other words, while the undamaged healthy skin of the disease-free tuber functions as a semi-permeable or selective covering to the storage tissue beneath it, the damaged skin of the blight-infected tuber no longer possesses this property. The entry of the acid through the skin and buds is well shown in Plate LX. ; in the original objects which these plates represent, the lighter diffusion zones or areas are very clearly differentiated from those portions of the tissue into which the acid has not diffused, by a pink coloration ([1]).

Certain observations by Wütrich[2] on the toxicity of H_2SO_4 in dilute concentrations on the conidia and zoospores of *Phytophthora* are of interest.

In each instance the period of observation covered 15 hours, and the following results are recorded :—

Strength of acid	*Phytophthora infestans*, De Bary.
0.0049 per cent - - -	Within 15 hours conidia neither form swarm spores nor directly germinate

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[1] Sections should be examined as early as possible after cutting, since after a few hours, desiccation at the surface leads to the diffusion of alkali.

[2] Zeit. f. Pfl. 1892, 16-31, 81-94.

Strength of acid	*Phytophthora infestans*, De Bary.
0.0049 per cent and malt extract	Conidia, an injurious effect is evident
0.0098 per cent and malt extract	Conidia, absolutely no germinative processes take place
0.0049 per cent - - -	Zoospores, motility of spores immediately arrested, germination suppressed.

The amount of acid which diffuses into the treated undamaged tuber, calculated as a percentage on total weight of tissue is 0.089 per cent. In the case of blight-infected material, the percentage absorbed is certainly higher. In either case, the diffused acid is distinctly localised and consequently in those portions of tissue into which it has penetrated the percentage will be greater than the above value.

In view of Wütrich's observations, the death of the fungal mycelia after the treatment of blight-infested tubers, with 10 per cent. acid is therefore easily conceivable.

Summary.

The results embodied in this paper may be briefly summarised :—

(1) When intact, blight free, mature tubers are steeped in aqueous solutions of the various chemical substances enumerated in this paper, the entry of the solute during the earlier stages of immersion is chiefly if not solely *via* the buds of the tuber.

(2) A steep of 10 hours' duration in a 10 per cent. solution of aqueous sulphuric acid suffices to destroy the vitality of the buds of the tubers, steeped in this reagent.

(3) A steep of 10 hours' duration in a 10 per cent. solution aqueous sulphuric acid suffices to destroy the vitality of the buds and also that of the fungal mycelia in the case of blight infested tubers. The solute in this case not only enters *via* the buds but

also through those parts of the skin which have been damaged by the ravages of fungus, or other parasitic organisms.

(4) It is essential to add that the results so far related in regard to the storage qualities possessed by acid treated tubers refer solely to the results obtained with fully matured, sound tubers.

It is hoped that facilities will shortly be provided for the further prosecution of this investigation.

I desire to express my acknowledgments to my colleagues, Mr. A. J. Despeissis, Commissioner for Tropical Agriculture, for his interest, suggestions, and valuable criticism; and to Mr. L. J. Newman (Entomologist) for loyal and intelligent assistance during the progress of this investigation. My best thanks are also due to Mr. Pether, Government Lithographer, Perth, for the series of excellent illustrative photographs, which he has been good enough to prepare from his negatives.

EXPLANATION OF PLATES.

Plate LVII.

Mature Victorian thick-skinned tubers, 10 % H_2So_4 treatment; experiments 5, 6, 7, storage tests.

Plate LVIII.

Mature Victorian thick-skinned tubers, 10 % H_2So_4 treatment; experiments 5, 6, 7a, and untreated control planting tests.

Plate LIX.

Mature Victorian thick-skinned tubers, 10 % H_2So_4 treatment, experimenting 7, planting test. Three tubers on removal from soil 40 days after planting.

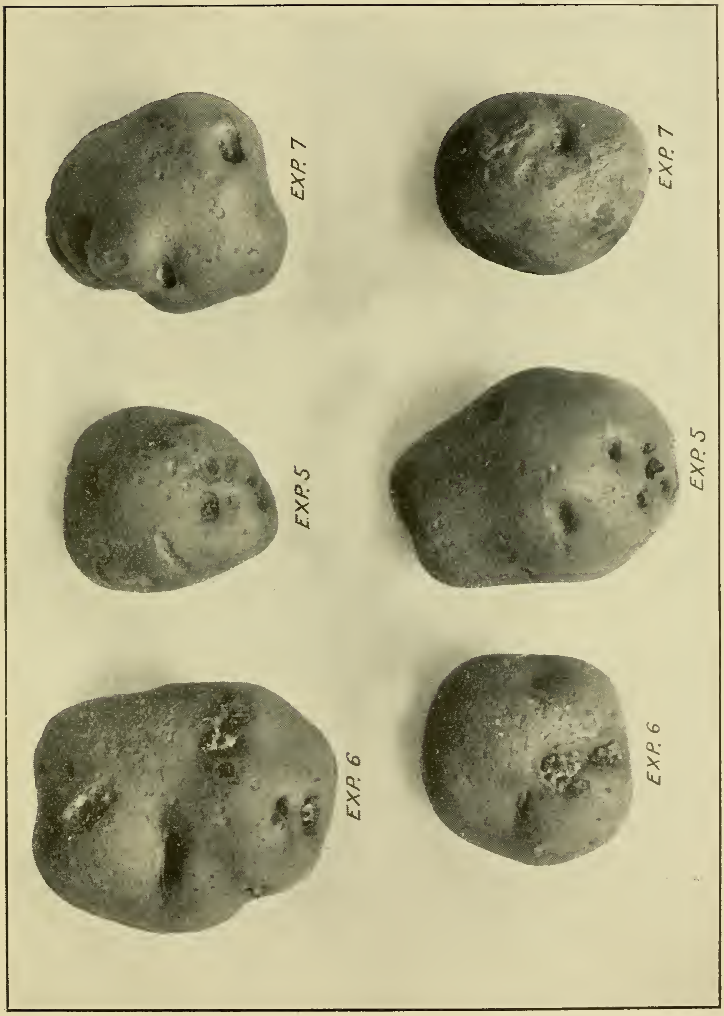
Plate LX.

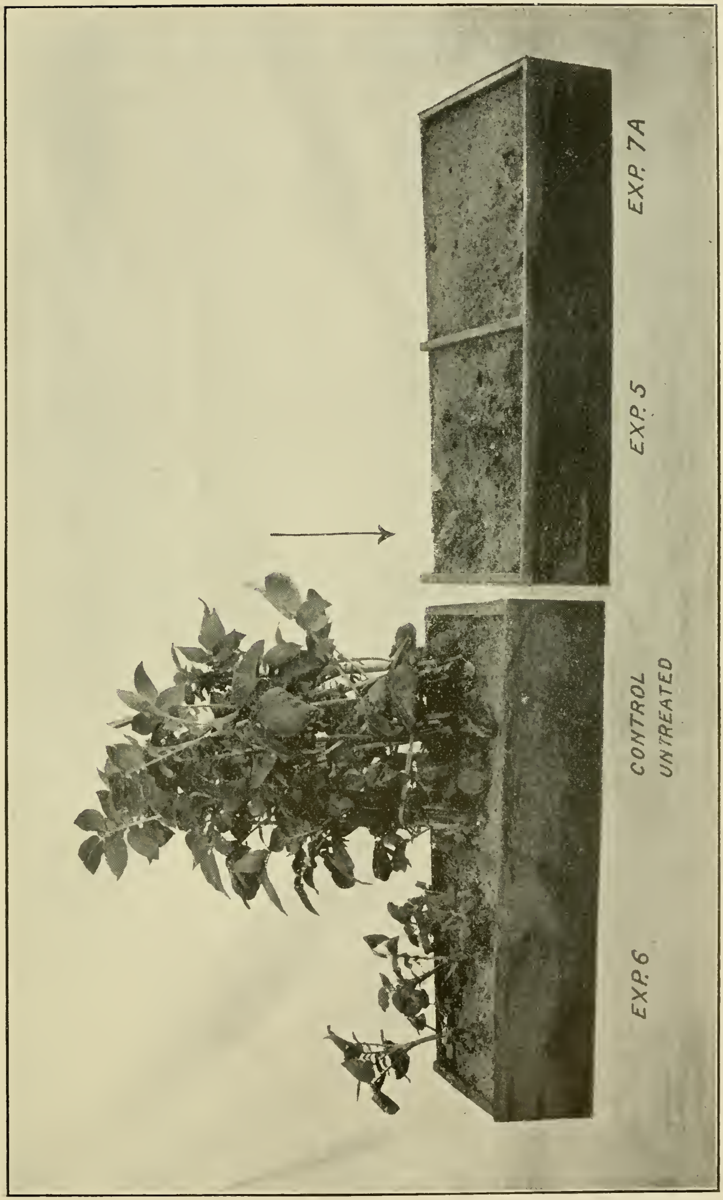
Entry of acid into blight-free and blight-infested tubers.

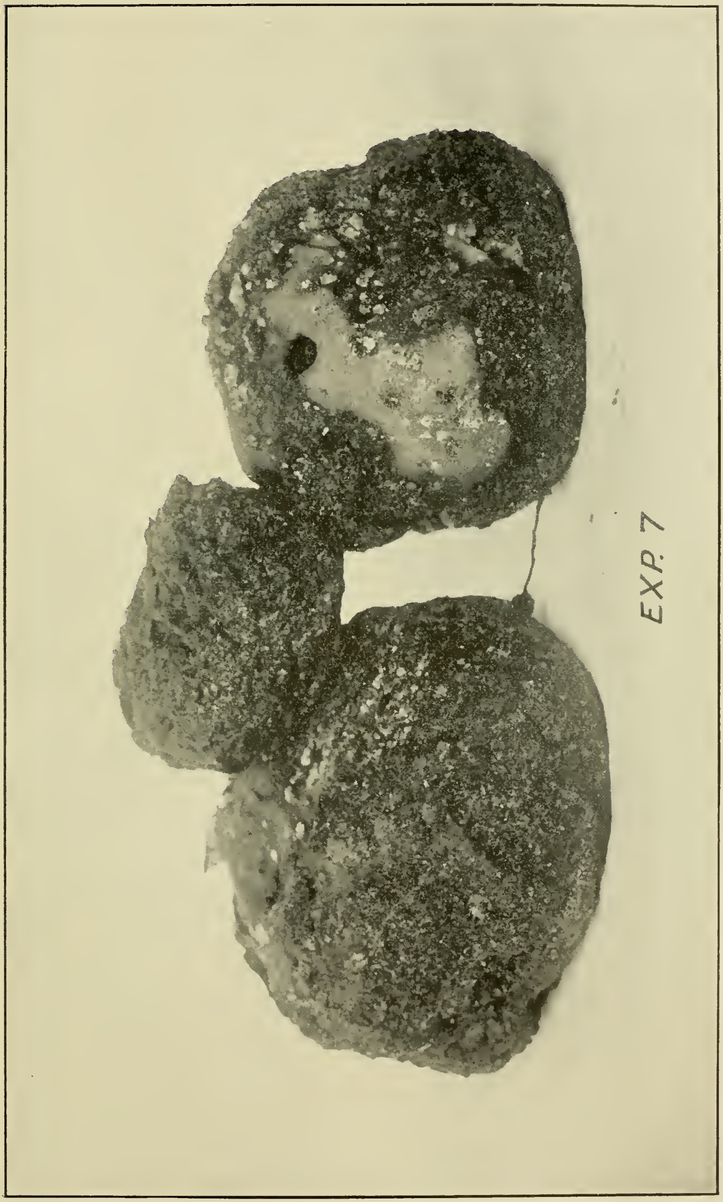
Expt. 1.—Cross section of blight-free tuber after steeping 20 hours in aqueous methyl orange. The arrows in this and succeeding figures indicate the position of the bud.

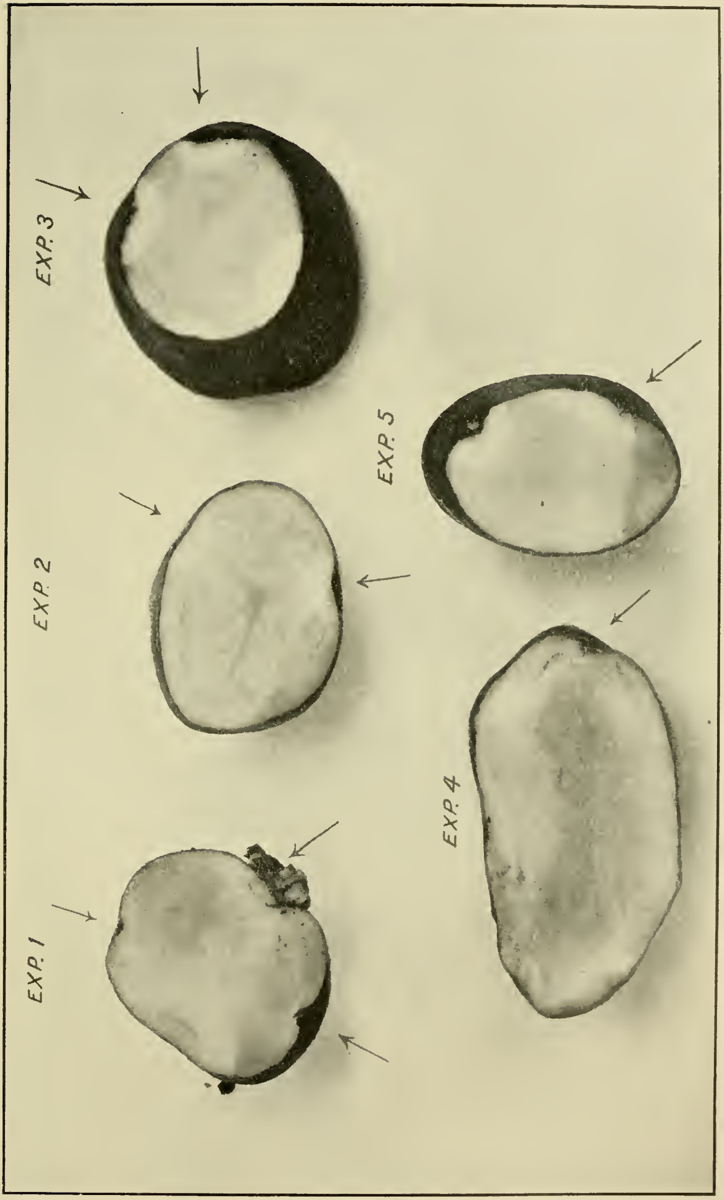
Expt. 2.—Cross section of blight-free tuber after steeping 20 hours in 10 % H_2So_4 and methyl orange. It will be noted that the entry of the acid is exclusively confined to the buds.

Expt. 3, 4, 5.—Cross section of blight infested tubers after 20 hours steeping in 10 % H_2So_4 and methyl orange. The points of entry of the acid through portions of the skin damaged by the ravages of the blight fungus are shown.


EXP. 7
EXP. 7
EXP. 5
EXP. 5
EXP. 6
EXP. 6


EXP. 6
CONTROL
UNTREATED
EXP. 5
EXP. 7A


EXP. 7


EXP. 1
EXP. 2
EXP. 3
EXP. 4
EXP. 5

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXI.—*New or Little-Known Victorian Fossils in the National Museum.*

Part XIV.—On some Silurian Trilobites.

By FREDERICK CHAPMAN, A.L.S., &c.

(National Museum, Melbourne).

(With Plates LXI-LXIII).

[Read 2nd November, 1911].

Introductory Remarks.

The trilobite fauna of the Victorian silurian beds is exceedingly rich, as proved by the large number of new forms being gathered into the Museum collections. It was at first intended to deal with the group as a whole in monograph form, but since this would involve more time than could be spared from other more urgent work at present, it seemed better in the meantime, to submit for publication descriptions of a few of the more interesting species.

The forms described below show many points of affinity with trilobites already known from Europe and North America. Perhaps the most interesting of these is the occurrence of a species, *Homalonotus vomer*, allied to the well-known wenlock guide fossil, *H. delphinocephalus*, Green sp. A noteworthy feature of the occurrence of this species at Wandong is its association with *Dalmanites meridianus*, Eth. fil. and Mitch., sp., a trilobite closely allied to the wenlock species, *D. caudatus*.

The following forms are here described:—

Ampyx parvulus, Forbes, var. *jikaensis*, var. nov.
Ampyx yarraensis, sp. nov.
Illaenus jutsoni, sp. nov.
Encrinurus (*Cromus*) *spryi*, sp. nov.
Homalonotus vomer, sp. nov.

Fam. TRINUCLEIDAE.

Genus **Ampyx**, Dalman.

Ampyx parvulus, Forbes, var. *jikaensis*, var. nov.
Pl. LXI., Figs. 1, 2).

Description of the Victorian variety.—

The holotype selected is a nearly entire carapace, but without genal and frontal spines; whilst on the same slab are several impressions of the thorax and pygidium of the same form. Another specimen, from Mr. Spry's collection, shows a faint impression of the base of a frontal spine. In its subcircular contour, strongly convex and oval glabella, with deep sulci separating it from the cheeks, this variety closely resembles Forbes' species[1]. The axis, however, is somewhat narrower in the Australian variety, being about one-fourth of the entire width of the carapace at the widest part of the thorax. The pygidium differs also from the British specimens in being slightly shorter in proportion to breadth. The thoracic segments, as in the type species, number five.

Dimensions. Length of carapace from anterior border of glabella to end of pygidium, 5 mm.; greatest width, 4.5 mm.; length of cephalon, 2.25 mm.; length of thorax, 2 mm.; length of pygidium, 0.75 mm.

Observations.—In Britain *A. parvulus* is recorded from the caradoc series (upper ordovician) and from the wenlock shale (upper silurian).[2]

The varietal name *jikaensis*, attached to the Australian specimens is derived from the parish name of the locality where it is found, Jika-jika.

This appears to be the first occurrence of the genus in Australia.

Occurrence.—In black, micaceous shale of silurian (melbournian) age. Moonee Ponds Creek, near Melbourne. Found and presented by Mr. J. Sidney Green. Mr. F. P. Spry, who has also found this form at the same place, informs me that this shale was obtained about 20 or 30 feet down in a shaft near the Moonee Ponds Race Course, and below the bed of the creek.

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[1] *Ampyx parvulus*, Forbes. Mem. Geol. Surv. Gt. Brit., vol ii., pt. 1. 1848, p. 350, pl. x., figs. 1, 1*a*, 2, 2*a*, 3.

[2] See Etheridge, Robt., Foss. Brit. Ids., vol. i., Palaeozoic., 1888, p. 40.

Ampyx yarraensis, sp. nov. (Pl. LXI., Fig. 3).

Description.—Cephalon only. Subtriangular, with a prominent lengthened, ovate glabella, strongly convex, pointed at both ends, with a deep, elongate depression on each side near the base. Anterior extremity of glabella terminating in a long, flexible spine, nearly equal to the length of the glabella, and evidently originally much longer. A deep sulcus separates the cheeks from the glabella. Fixed cheeks triangular, with a convex anterior border and well-marked basal furrow. Neck ring of glabella narrow.

Dimensions.—Width of cephalon, 7.5 mm.; length of glabella, 4.75 mm.; length of spine, 4.25 mm.; width of glabella, 2.75 mm.

Affinities.—The nearest form to the present species appears to be "*Raphiophorus*" *culminatus*, Angelin[1]; but its cephalon is narrower. Angelin's species occurred in the ordovician (trinucleus schists and limestones) of Mount Kinnekulle, Sweden.

Occurrence.— In yellow mudstone of silurian (melbournian) age. South Yarra (Yarra Improvements). Coll. by Mr. F. P. Spry.

Fam. ASAPHIDAE.

Genus **Illaenus**, Dalman.

Illaenus jutsoni, sp. nov. (Pl. LXI., Figs. 4, 5).

Description.—A small species for this genus. Form, long, oval. Head semi-oval; highest along the median line, roundly sloping to the lateral and frontal margins. Axal furrows well impressed at the posterior margin, ceasing a little beyond the top of the eyes. The eyes narrow, (?) sub-elliptical or lunate. A narrow and rounded median fold or ridge extends along the summit of the glabella, tapering off into a mere thread before reaching the anterior margin. Facial suture nearly the same as in *I. davisii*, but straight rather than concave when nearing the posterior margin. Anterior border somewhat narrow and

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[1] Pal. Scand., 1854, p. 82, pl. xl., fig. 8.

evenly rounded. Lateral border rounded, and prolonged posteriorly into a short genal process. Thorax moderately convex along the median line. Axal furrows well marked. Body rings ten, short, of even width, gently curved on the axis, smooth, with granulate or striate margins. Pleura moderately narrow; about half the width of the axal segments. Fulcrum somewhat sharply bent; distal portion of pleura pointed at the extremities. Pygidium long, semiovate, convex in median area; surrounded by a moderately broad fascia of even width, finely striate. Axis continued some way into the tail, defined by two rapidly converging furrows, the extent of which is not clear in the specimen described.

Dimensions.—Approximate. Specimen slightly and obliquely crushed. Total length, 37.25 mm.; length of cephalon, 14 mm.; width of cephalon, (cir.) 16 mm. ; length of thorax, 7.25 mm.; greatest width of axis, 10 mm.; width of pleura (cir.) 3.25 mm.; length of pygidium, 16 mm.; width of fascia, 2.25 mm.

Affinities.—This handsome and distinct species is a typical *Illaenus*, in having ten body rings and a moderately narrow axis. One of the nearest related species is *I. davisii* Salter[1] (= *I. crassicauda*, Sharpe), which is proportionally wider than the present species, has a broader and more tumid cephalon, blunt, genal angles, longer lateral pleura, and a rounder and shorter pygidium. Moreover the ornamentation of the glabella is a distinguishing feature in the Victorian specimen. It is of especial interest to note that the British *I. davisii* is found in the more argillaceous parts of the Bala limestone (upper ordovician) in Wales; and it also occurs in strata of equivalent age in Scotland.

Other simulant forms, both from the llandovery series (base of silurian proper) are *Illaenus maccallumi*, Salter[2], and *I. nexilis*, Salter[3]. The first-named, however, is a *Bumastus*, with a typically broader body and well-developed eyes; whilst the second belongs to the section *Dysplanus*, with only nine body rings.

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[1] Mem. Geol. Surv. United Kingdom; Brit. Foss., Dec. ii., 1849, pl. ii.

[2] Mon. Sil. Trilobites (Pal. Soc. Mon., vol. xx.), 1867, p. 210, pl. xxvii., fig. 1; pl. xxx. figs. 2, 3.

[3] Ibid., p. 190, pl. xxx., figs. 4, 5.

Two Australian species of this genius have been recorded. In the first place de Koninck[1] doubtfully refers to a minute pygidium from the silurian limestone at Boree Cave, New South Wales, to *I. wahlenbergi*, Barrande; but in the absence of a full description, figures, or the type specimen, it is impossible to discuss this reference. *I. wahlenbergi* of Barrande[2] is a shorter and stouter form than the present, and has prominent, extended, genal spines; whereas in *I. jutsoni* the genal processes are closely adpressed to the upper part of the thorax. The second specimen known from Australian rocks is *I. johnstoni*, Eth. jnr.[3] described by Mr. Etheridge from the silurian of Zeehan, Tasmania; and from rocks of like age at Borenore near Orange, New South Wales. This latter species is, as Mr. Etheridge points out, of the type of *I. murchisoni*, Salter.

Occurrence.—In olive-brown indurated mudstone of silurian (melbournian) age. From a quarry between Heidelberg and Templestowe. Collected and presented by Mr. J. T. Jutson.

Fam. ENCRINURIDAE.

Genus **Encrinurus**, Emmrich.

Subgenus **Cromus**, Barrande.

Encrinurus (*Cromus*) *spryi*, sp. nov. (Pl. LXII., Fig. 1).

Description.—Carapace sub-oval; anterior broad, roundly acuminate at posterior extermity. Central axis prominent; pleural areas strongly convex.

Cephalon hemispherical, less than half as long as wide. Glabella subpyriform, comparatively narrow behind, finely tuberculate anteriorly, and with two deep, transverse sulci above the neck rings, interrupted in the middle. Fixed cheeks sometimes tuberculate, with a deeply grooved posterior margin. Eyes prominent, not often well preserved in these specimens.

Thoracic segments eleven, comparatively narrow and crowded; axis slender, about one-quarter the width of the carapace; pleura thickened or tuberculate at the axal furrow.

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[1] Descr. Pal. Foss. N. S. Wales.—Mem. Geol. Surv. N. S. Wales, Pal., No. 6, 1898, p. 36.

[2] Nouv. Trilob., 1846, p. 13. Also Syst. Silur. Bohême, 1852, vol. i., p. 684, pl. xxxiv., figs. 19-24.

[3] Tasmania; Report of the Secy. for Mines for 1895-6, p. xlii., pl.—, fig. 3. Also Rec. Geol. Surv. N. S. Wales, vol. viii., pt. iv., 1909, p. 319, figs. 1, 2.

Pygidium short, subtriangular, with rounded sides and a bluntly acuminate extremity.

Dimensions.—Length of type specimen, 17 mm.; greatest width, 11 mm.; length of cephalon, 4.75 mm.; length of thorax, 7 mm.; length of pygidium, 5.25 mm.

Observations.—A species described by A. F. Foerste[1], under the name of *Encrinurus mitchelli*, bears some relationship to the present form. It was described from specimens sent by Mr. J. Mitchell from the silurian of Bowning, New South Wales. When on a recent visit to Melbourne Mr. Mitchell saw the present specimens and suggested that they were the same as *E. mitchelli.* Since then I have carefully examined a large series of specimens in the National Museum collection from the Yarra Improvement Works and elsewhere near Melbourne, and have drawn the conclusion that they are distinct from the Bowning species although bearing strong affinities to them. The specimens here selected as the holotype of *E.* (*C.*) *spryi* was that labelled by Sir F. McCoy shortly before his decease, and that name is here retained. The differential characters between *E. mitchelli* and *E.* (*C.*) *spryi* are these, viz., in the former the carapace is longer; the axis is broader; the glabellar furrows are almost obsolete; the pygidium has nearly straight instead of curved sides; and the extremity is more acuminate, as in a typical *Encrinurus.*

Occurrence.—In grey mudstone and shale from the Yarra Improvement Works, South Yarra. Also in various excavations in Melbourne. This is the commonest trilobite in the Melbourne bed-rock. Silurian (melbournian). Type presented by Mr. F. P. Spry in November, 1897.

Fam. CALYMENIDAE.

Genus **Homalonotus**, Koenig.

Homalonotus vomer, sp. nov. (Pl. LXII., Figs. 2, 3, Pl. LXIII., Figs. 1, 2).

Description.—This species, having an elongate, convex, triangular head, with a lobed glabella and non-remote eyes, falls within the section *Trimerus* of Green. In general form it closely approximates to *H. delphinocephalus* of the woolhope and wenlock limestone of England, and the Niagara limestone of North America. It differs, however, from that species in the shape of the anterior part of the cephalon and in some minor details.

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[1] Bull. Sci. Lab. Denison Univ., vol. iii. 1886, p. 124, pl. xi figs. 2, 3, 20.

In general form *H. vomer* is elongate or long ovate, broadest at base of cephalon, tapering to a point behind; back depressed convex, with deflected sides. Cephalon triangular, acuminately arched in front with a strongly depressed surface[1], granulate; glabella subtriangular, truncated anteriorly, with a central, longitudinal crest and three pairs of furrows trending upwards and outwards. Eyes prominent, distant, a little more than half the width of the cephalon. Neck furrow sharply defined in the middle axal region, and by a broader depression at the base of the fixed cheeks.

Thoracic segments well defined, about thirteen; axal furrows broad, pleura bending sharply down at the fulcra.

Pygidium long and slender, more acutely pointed than in *H. delphinocephalus.* Surface of carapace finely granulate. Judging from the type specimen, the power of enrolment was great. Although not so long as its nearest ally, *H. delphinocephalus,* this species must have been a handsome form when living.

Dimensions.—Type specimen. Length of cephalon, 32.5 mm.; width of cephalon, 46 mm.; length of glabella, 18 mm.; width between eyes, 27 mm.

From another specimen of similar size. Length of thorax, 59 mm.; width of thorax, 43 mm.; width of pleura in middle of thorax, 4.5 mm.; length of pygidium about 38 mm.

Occurrence.— Silurian. Wandong, Victoria. Type specimen presented by Mr. J. T. Jutson. Paratype presented by Mr. G. Sweet, F.G.S. A cephalon of a young specimen (additional paratype), presented by Mr. F. P. Spry.

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[1] Reminding one of a ploughshare, hence the specific name.

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EXPLANATION OF PLATES.

PLATE LXI.

Fig. 1.—*Ampyx parvulus*, Forbes, var. *jikaensis*, var. nov. Holotype. Silurian (Melbournian). Moonee Ponds Creek, Vict. × 2. Coll. and pres. by J. S. Green.

Fig. 2.—*A. parvulus*, Forbes, var. *jikaensis*, var, nov. Paratype. Cephalon with proximal part of frontal spine. Silurian (melbournian). Moonee Ponds Creek. × 2. (Spry coll.).

Fig. 3.—*A. yarraensis*, sp. nov. Holotype. Silurian (melbournian). South Yarra. × 2. Coll. F. P. Spry.

Fig. 4.—*Illaenus jutsoni*, sp. nov. Holotype. Silurian (melbournian). Near Heidelberg, Vict. Coll. and pres. by J. T. Jutson. Nat. size.

Fig. 5.—*I. jutsoni*, sp. nov. Profile of carapace of foregoing specimen. Nat. size.

PLATE LXII.

Fig. 1.—*Encrinurus spryi*, sp. nov. Holotype. Silurian (melbournian). South Yarra. Coll. and pres. by F. P. Spry. Slightly larger than nat. size.

Fig. 2.—*Homalonotus vomer*, sp. nov. Cephalon of holotype. Silurian. Wandong, Vict. Slightly larger than nat. size.

Fig. 3.—*H. vomer*, sp. nov. Holotype. Silurian. Wandong, Vict. Coll. and pres. by J. T. Jutson. Nat. size

PLATE LXIII.

Fig. 1.—*Homalonotus vomer*, sp. nov. Plesiotype. Head of immature specimen. Silurian. Wandong, Vict. Coll. and pres. by F. P. Spry. Slightly larger than nat. size.

Fig. 2.—*H. vomer*, sp. nov. Paratype. Thorax and pygidium. Silurian. Wandong, Vict. Coll. and pres. by G. Sweet, F.G.S. Slightly less than nat. size.

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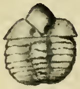

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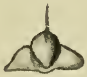

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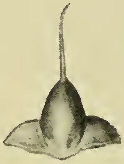

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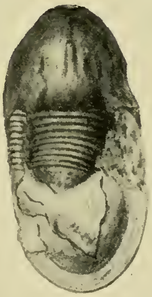

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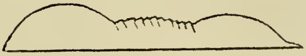
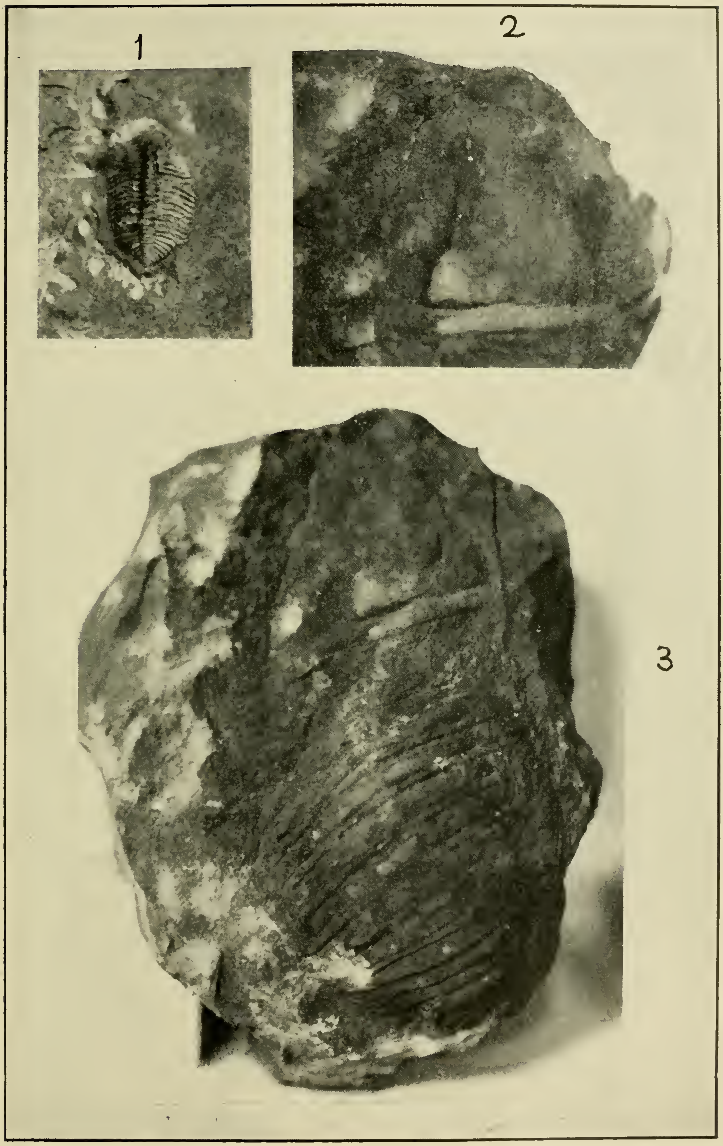


F.C. ad nat. del.

Silurian Trilobites.—Victoria.



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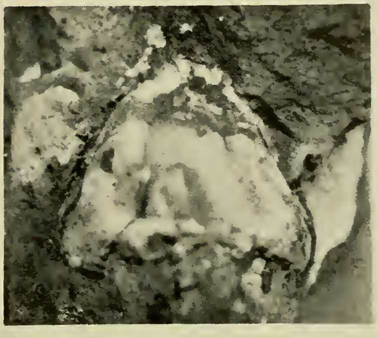
Silurian Trilobites.—Victoria.



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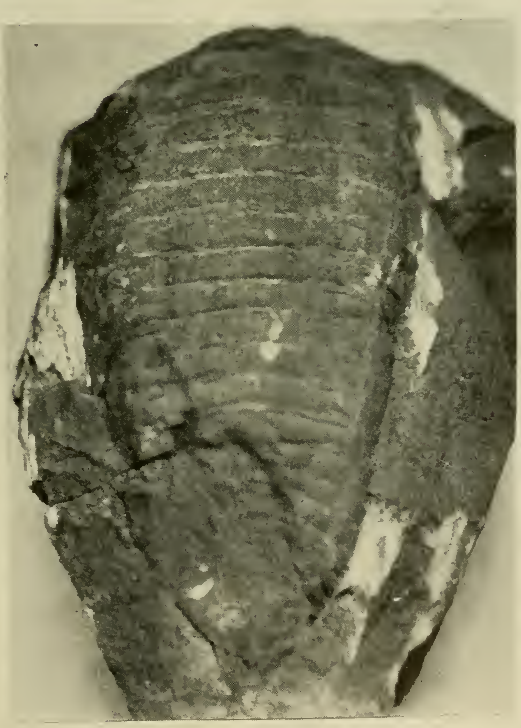

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F.C., Photo.

Silurian Trilobites.—Victoria.

[PROC. ROY. SOC. VICTORIA, 24 (N.S.) PART II., 1911].

ART. XXII.—*Flotation of Minerals.*

PART II.

BY KENNETH A. MICKLE

(Government Science Research Bursar, Melbourne University, and Associate Working Men's College, Melbourne.)

[Read 4th December, 1911].

As stated in my paper read before this Society in December, 1910, the various flotation processes which are now being so largely used for separating metallic sulphides from sulphide ores depend upon differential gas and liquid attaching phenomena. The sulphides are floated (on aqueous solutions) as a sort of scum or froth by the agency of either gases alone or by gases assisted by small proportions of various oily substances. The paper referred to contained the results of investigation bearing on these gases and liquid attaching phenomena, and the present paper deals with a continuation of this work.

The attachment of gases and liquids to solids and to each other with special reference to flotation processes.

As oils and other substances of an oily nature are being extensively used in these processes, the behaviour of these substances under varying conditions was investigated.

In a paper[1] by Lord Rayleigh it was shown that the presence of small proportions of various contaminants in water very materially affected its frothing properties. Pure water on being vigorously agitated with air shows very little tendency to produce a froth. This tendency is very much increased by the addition of small proportions of some substances, as saponine and acetic acid. These contaminants include not only substances which are soluble in water, such as saponine and acetic acid, but substances which are insoluble in water, such as various oils and certain finely divided solid substances.

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[1] "On the tension of water surfaces clean and contaminated." Phil. Mag. xxx., Nov. 1890, pp. 386-400.

"Experiments with surface films." Phil. Mag. xxxiii., 1892, pp. 363-373.

"On the theory of Surface Forces: Effects of slight contaminations." Phil. Mag. xxxiii., pp. 468-471.

"Investigations on Capillarity." Phil. Mag. xlviii., 1899, pp. 321-337.

Without doubt liquid cohesion and attachment effects are important factors in determining froth producing variations, but it seems apparent that gas attachment is the chief factor, and a comparison of the various proportions of froth produced would therefore afford an approximate measurement of the attachment of air to water and to various aqueous solutions and mixtures.

The following list shows the order in which a series of various substances came in their froth producing effects. In each case one drop of the contaminant was mixed with 60 c.c. of pure water and agitated vigorously with air, the froth produced being noted:—

1. Saponine (greatest froth).
2. Turpentine.
   Phellandrene.
   Residual oil (from rectification of eucalyptol).
3. Tasmanian refined petrol (0.754).
   Acetic acid.
4. Eucalyptol, crude shale oil (0.900).
   Cotton seed oil.
5. Oleic acid.
   Combustion engine oil (0.831).
6. Tasmanian shale residual oil.
   Tasmanian shale turps. substitute.
   Austral machine oil.
7. Kerosene.
8. Alcohol, oil of winter-green, naphtha, gasolene, ether (petroleum), ether (sulphuric).

The froth produced by the last contaminants in the series was practically the same as with pure water.

With the view of obtaining some confirmation of the above series of results the following experiments were carried out:—

1. Agitation with air, 60 c.c. of water and 10 c.c. of the various contaminants.

2. Agitation with air each of the various contaminants alone.

The results of these experiments are given below:—

Agitation with air and 60 c.c. of water and 10 c.c. of each of the contaminants:—

1. Saponine (most persistent froth).
2. Naphtha.
3. Kerosene.
4. Austral machine oil.
5. Oleic acid.
6. Turpentine.
7. Phellandrene.
8. Eucalyptol.
9. Gasolene.
10. Alcohol.
11. Acetic acid.
12. Glycerine (practically no froth).

Agitation with air, each of the various contaminants alone:—

The order in this instance is practically the same as that in the series where one drop of the contaminant to 60 c.c. of water was used. The froth produced is, however, less than when the water is present.

It is difficult to reconcile these three series of results. The variations may be due to the varying gas and liquid attachments under the different conditions.

It being apparent that the opacity of the various mixtures of oil and water after agitation would afford some indication of the measure of attachment of one to the other, the following series of opacity observations were made.

In each case one drop of the contaminant was added to 60 c.c. of water and agitated with air, and after standing the opacity of the solution due to the emulsion formed was observed.

1. Oil of winter-green: greatest opacity.
2. Turpentine, cotton-seed oil.
3. Residual oil from rectification of eucalyptol.
4. Austral machine oil.
5. Phellandrene.
6. Kerosene.
7. Naphtha.

In the case of the other substances a clear solution resulted.

These solutions in some cases still showed opacity after standing for a week.

When 10 c.c. of the substance was added to 60 c.c. of water and agitated with air, after standing for some time, a layer of white emulsion was noticed between the layer of oil and the surface of the water. This was greatest in the case of machine oil and oleic acid.

The following list gives the order in which the various substances come with regard to the amount of emulsion formed:—

1. Machine oil and oleic acid.
2. Oil of winter-green.
3. Naphtha.
4. Kerosene.
5. Eucalyptol.
6. Turpentine.

The other substances showed no emulsion.

In the case of oil of winter-green, the emulsion occurred on the top of the oil, which, being heavier than water, sank to the bottom of the measuring cylinder.

In conducting these tests with oils and water, it was noticed that some oils at once spread out to form a film over the surface of the water, while others remain in the form of a globule.

Some of the light thin oils when added as a drop to a large surface of water will spread out in a very thin film to such an extent that the iridescence disappears in the centre of the area.

The following oils spread out as a thin film on the surface of water when the oil was added as a drop to the water:—turpentine, phellandrene, gasolene, naphtha, eucalyptol, kerosene. Oleic acid formed a film with one drop, but on adding another drop, the second remained as a globule.

The following oils remained as globules on the surface of the water:—cotton seed oil, machine oil, engine oil.

This property of oil depends apparently to a large extent on the viscosity of the oil, for as a rule, and with the thin oils, a film was formed, and with the thicker oils the drop remained as a globule. Viscosity is not, however, the only determining factor, as some of the more viscous oils were found to form films, and some interaction between the surfaces of the oil and water must take place.

The adsorption of oil by minerals.

The effect of oils has long been known in protecting minerals from being wetted by water, owing to the oiling of their surfaces, and also the affinity of oils for metals and many metallic substances. As no accurate method of measuring this affinity or attraction has suggested itself, and as minerals may occur in many different forms with varying physical characters, no attempt is made here to make a definite classification on this basis. Tests were, however, carried out to show the amount of oil absorbed by minerals, and the character of the resultant product.

Mixtures of the mineral to be tested, water, and oil (with and without a small quantity of acid) in definite quantities were taken and agitated thoroughly till the character of the resultant product became constant.

The results of these tests showed that while there are undoubtedly differences in the degree of attraction between a given sulphide and various oils, and between various sulphides and a given oil, the general behaviour between various sulphides and various oils in the presence of water is practically the same in characer, i.e., all sulphides will become attached to all oils in preference to water. With the silicates and other rock minerals usually found in the gangue material of ores, the character of the product varies with different minerals.

In the case of sulphides, bottles were taken containing 200 c.c. water, 5 gms. of the oil being used, and 0.5 gm. sulphuric acid. Increasing amounts of the sulphides were added to each bottle, and well agitated to bring the mineral into intimate contact with the oil.

The following is a summary of the results obtained from these experiments:—

In acidulated solution.

In the first test zinc blende crushed to pass a 40-mesh sieve was used with a heavy engine oil.

The contents of the bottles were as follows:—

Water, 20 c.c.; oil, 5 gm.; sulphuric acid, 0.5 gm.

To No. 1 bottle, 1 gm. of the mineral was added.
,, ,, 2 ,, 5 ,, ,, ,,
,, ,, 3 ,, 10 ,, ,, ,,
,, ,, 4 ,, 20 ,, ,, ,,
,, ,, 5 ,, 30 ,, ,, ,,
,, ,, 6 ,, 40 ,, ,, ,,
,, ,, 7 ,, 80 ,, ,, ,,
,, ,, 8 ,, 120 ,, ,, ,,

If any intermediate or greater quantity of mineral was needed to fix a certain point, e.g., 60 or 200 gms., another bottle was added to the series as required.

With the proportion of 1 gm. blende to 5 gms. oil, on agitating, some of the blende floated on the solution, being buoyed up by the oil and entangled air bubbles. On standing, all the mineral sank to the bottom of the bottle, carrying large "blobs" of oil with it. The product formed by the oil and blende was oily and non-miscible with the solution. An excess of oil floated on the surface of the solution and adhered to the surface of the glass above the level of the solution.

With 5 gms. blende much oil was carried down with the blende, but on standing some of it broke away and came to the surface of the solution again, leaving an oily mass non-miscible with the solution. An excess of oil showed on the surface and adhering to the glass above the level of the solution.

With 10 gms. a heavy, freely flowing oily magma was formed below the solution. The excess of oil still showed on the surface of the solution.

With 20 gms. of the blende the oily product became more putty-like in appearance, and moved less freely than with 10 gm. An excess of oil still showed on the surface of the solution and on the bottle.

With 30 gms. a putty-like plastic mass was formed by the blende and oil, which was very difficult to break up on agitation. A slight excess of oil still showed on the surface of the solution.

With 40 gms. the product broke up into large rounded lumps on agitation. No excess of oil showed on the surface of the solution or on the bottle. On violent agitation a few bubbles of air became attached to the mass.

With 80 gms. the product of the oil and blende consisted of a mass of small coherent aggregations, which on violent agitation attached many air bubbles, but which would not float the mineral.

With 120 gms. the aggregates of blende and oil were smaller and less coherent. The zinc blende at this stage seemed more prone to attach air bubbles, and showed a tendency to float.

The appearance of the product was quite different from a similar quantity of unoiled blende in water.

Another series on the same lines as the above, using galena and oleic acid in similar proportions to the blende and engine oil, showed that the general character of the products was similar to those produced with blende and engine oil.

The oily magmas on the bottom of the bottles formed by the galena and oleic acid were less viscous and flowed more freely. A little free oil still showed on the surface of the water when 40 gms. galena had been added. No free oil showed with 80 gms. The products with 80 gms. and 120 gms. galena were more coherent and less prone to attach bubbles of air than was the case with zinc blende. The stage at which the small granules formed was less marked with the galena than with the blende.

In another series with heavy lubricating oil and zinc blende, most of the oil was carried down to the bottom in the form of a putty-like ball with the blende when 30 gms. of the latter had been added. This plastic mass would not break up on shaking violently, and was not miscible with the solution.

With 20 gms. of the blende and the oil, the product was a thin plastic mass on the bottom of the bottle, and non-miscible with water. A large excess of oil showed on the surface of the water.

With 40 gms. of blende, the mass or magma showed a tendency to break up into small lumps, but showed no tendency to attach air bubbles. The lumps were rounded and were about the size of broad-beans. No free oil showed on the surface of the water.

In another series using copper pyrites and 5 gms. heavy engine oil, all the oil was carried down with 30 gms. of the copper pyrites, to form the putty-like magma which would not break upon agitation.

When 40 gms. had been added the magma showed a tendency to break up on agitation into smaller lumps, but showed no tendency to attach air bubbles.

With 80 gms. of copper pyrites the product formed was a mass of coherent aggregates under the solution, each aggregate being about the size of fishes' roe.

With 120 gms. many air bubbles became attached, and a marked tendency to float was shown. The aggregates were smaller than when 80 gms. of copper pyrites had been added.

With galena and kerosene all the oil was not carried down till 80 gms. had been added. The products were less coherent and less viscous than with the thicker oils.

With galena and petrol a considerable excess of oil showed on the surface of the water when 40 gms. of the galena had been added.

Using machine oil with galena, very little excess of oil showed on the surface when 30 gms. galena had been added, and no excess showed with 40 gms. With 60 gms. galena the magma showed a tendency to break up on shaking and to attach air bubbles.

With 5 gms. cotton seed oil and galena a small excess of free oil appeared on the surface of the water when 30 gms. galena had been added. No excess of oil showed with 40 gms. galena. The putty-like magma formed, but was not so viscous as with the thicker oils. No distinct stage occurred at which the oily magma broke up into smaller rounded lumps, as in the case with some of the oils.

With 60 gms. a tendency to attach air bubbles was shown by the magma, and when 80 gms. galena had been added some of the galena would float on agitation.

Using a eucalyptus oil containing 80 per cent. phellandrene, it was not till 80 gms. of the galena had been added that all the oil was carried down. No distinct "putty" stage occurred, all the oily products being more or less like a freely moving pulp.

A series on the same lines as the above tests, but using minerals that had been "sized," was then tried. Some galena crushed to pass a 30-mesh (linear inch) sieve, but retained on a 40-mesh, was mixed with water and 5 gms. oleic acid, as in the other tests.

With 80 gms. galena a slight excess of oleic acid still showed on the surface of the water. All the oily products under the surface of the water were feebly coherent, but no distinct putty stage occurred. With 200 gms. galena a few air bubbles became attached.

Using galena crushed to pass an 80-mesh, and retained on a 120-mesh sieve, with 5 gms. oleic acid, all the oil was carried down with 60 gms. of the mineral to form the characteristic putty-like magma. A very small excess of oil showed on the surface of the water with 40 gms. of galena.

With galena crushed to pass 120-mesh sieve all the oil was carried down by 40 gms. of the mineral. When 30 gms. had been added, the plastic putty-like mass was formed. With 120 gms. of this sized galena to 5 gms. of the oleic acid, the product of the galena and oil was much less coherent than with 120 gms. of the galena crushed to pass an 80 and remaining on a 120-mesh sieve.

In water without the addition of acid.

The foregoing tests were carried out with water acidulated with 0.5 gm. sulphuric acid. The following is a short summary of the results of tests on the same lines, but using water which had not been acidulated.

Using galena crushed to pass 120-mesh sieve and 5 gms. of waste engine oil (fairly thick), the same general results were obtained as when acid was present. All the oil was carried down with 30 gms. of the galena. The putty-like magma occurred when 40 gms. had been added, this product being firmer than that formed with 30 gms.

When 60 gms. of galena had been added the magma broke up into granules. With 80 gms. of galena, air bubbles showed a tendency to become attached, and with 120 gms. galena a marked tendency to float on agitation was observed.

Other tests on the same lines without acid showed that with smaller proportions of oil to mineral the product was more prone to attach air bubbles and had a more flocculent appearance than when acid was present.

Two bottles containing 50 gms. galena and 0.8 gm. oleic acid with 200 c.c. water were taken, and to one of them 0.5 gm.

sulphuric acid was added. The appearance and character of the products formed after agitating vigorously differed from one another. The aggregations formed in the acidulated solution were less flocculent and showed less tendency to float on agitation.

Silicates and other gangue minerals:—*In water.*

The various silicates and other gangue constituents of sulphide ores when agitated with various proportions of oil and an excess of water exhibit a lesser tendency to attach the oil than the various metallic sulphides. This tendency to attach oil in preference to water is very small in the case of the more acidic minerals, and so great in the case of the more basic minerals that their behaviour approaches that of some of the metallic sulphides. For instance, with 40 gms. of quartz or orthoclase felspar, 5 gms. of oleic acid and 200 gms. of water, nearly the whole of the oil will separate and float on the surface of the water, and the mineral particles sink in the water without any sign of aggregation, a few scattered blobs of oil only being carried down with the mineral. On the other hand, with similar proportions of rhodenite and garnet, oil and water, the minerals unite with the oil to form coherent aggregations, and no oil separates as in the case of quartz and felspar.

Calcite also produces coherent aggregations with oil which, on agitation, readily attach air bubbles.

In acidulated solutions.

The addition of small proportions of acid (0.5 gm. sulphuric acid) to the water in all cases lessens the oil attachment. For example, on agitating the above proportions of quartz and oleic with acidulated water the quartz behaves as if no oil were present. This is also the case with orthoclase felspar.

With rhodonite and oleic acid, with acidulated water in the same proportions as before, free oil separates and floats on the surface of the solution. The product is a sandy pulp which is freely miscible with the solution. This pulp has an appearance very different from the product formed with the non-acidulated water, oil and rhodonite in the same proportions. With mixtures of galena and rhodonite, the oil collects the galena to form granules, and the rhodonite remains as a sandy pulp which could be washed out if desired. In cases of a mixture of a sulphide which will attach oil and a gangue mineral which, in an acidulated solution, will not attach oil, some of the gangue mineral is held mechanically by the sulphide aggregates, and thus may be caused to float, although having no natural tendency to do so. In such a case, what may be termed coadsorption may take place. For example, quartz sand by itself will not float with oil in a non-acidulated solution, but the particles of quartz sand in a gangue with other minerals, as in the case of Broken Hill tailings, are readily floated with oil in non-acidulated water. This coadsorption will take place in feebly acid solutions, and thus particles of rhodonite and other gangue may be caused to float.

From the above tests the following may be deduced:—

Adsorption of oil in water.

1. Finely divided sulphides when suspended in water will adsorb varying amounts of oil. Large proportions of oil tend to form magma, and smaller proportions plastic masses and coherent aggregates. The character of these oily magmas depends upon the amount and the character of the oil used. Thick oils give viscous coherent products, and thin oils give less coherent products. Oily magmas containing considerable proportions of oil will entangle and hold gaseous bubbles with a degree of persistency which depends on the viscosity of the oil.

Sulphides carrying an adsorption of about 5 per cent. of oil tend to attach gaseous bubbles, and this tendency increases as the proportion of oil diminishes, until a certain limit is reached which is 0.5 per cent. or thereabouts.

2. The adsorption is more pronounced with sulphides than with such minerals as quartz, felspar and most of the acidic rocky minerals forming the gangue of ores.

3. Some of the silicates and other gangue forming minerals will adsorb oils in a manner approaching that of the sulphides, for example, rhodonite, garnet, magnetite and calcite.

4. As shown by the tests on sized minerals the amount of oil adsorbed depends upon the extent of surface exposed.

In acidulated solutions.

1. The sulphides will adsorb oil in the same manner to form oily magmas, plastic masses and coherent aggregations, as in the case of water and oil without acid. The amount depends on the extent of surface exposed by the minerals, as previously.

2. The gangue minerals will not adsorb oils to nearly the same extent as when no acid is present.

3. The maximum amount of oil adsorbed by sulphides in a stable manner when crushed to pass through an 80-mesh sieve (linear inch) is in the neighbourhood of 10 to 15 per cent. of their weight. This is shown by the absence of excess of oil on the surface of the solution in the above tests when the percentage of oil to mineral was at or near these values. The tendency of the plastic magma to break up and form less coherent aggregates at this point also indicates this limit of true adsorption.

Conclusions.

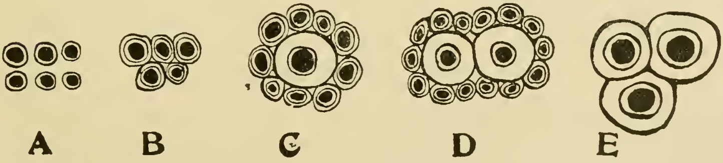
When finely divided metallic sulphides are vigorously agitated with an excess of water and a small proportion of oil, the oil is adsorbed by the sulphide particles. As shown by the previous tests on the sized material, the quantity of oil adsorbed depends upon the extent of the surface exposed. This being so, it seems safe to assume that the adsorbed oil is evenly distributed over the surface of the particles. When the quantity of oil adsorbed is very small, the general appearance of the sulphide does not differ from that of unoiled particles. With a sulphide such as galena, which has been crushed to pass through an 80-mesh (linear inch) sieve, this point of apparent difference is reached when the proportion of oil adsorbed (in the case of oleic acid) is between 0.05 and 0.10 per cent. Even with these small proportions, various physical tests indicate that the particles are oiled. This can be shown by their aversion to become wetted by water, and by the fact that the odour of decomposed oil is noticed on heating.

Such a quantity as 0.1 per cent. cannot be separated by squeezing, centrifugal force or other mechanical means, and any such quantity of adsorbed oil as 0.1 per cent. may be regarded as a true adsorption of the oil by the mineral. When more oil is added it is probable that a secondary envelope of oil becomes attached to the primary film. When this oil film is thin, there is still the attraction of the oil for the sulphide, but as the film becomes thicker the subsequent overlapping envelopes of oil are held by the attachment of one oil film for another. These overlapping films are less persistently held than the primary films, and some of the oil can be separated mechanically, as by pressure or centrifugal force. The point at which the secondary film is thickest and still stable is represented in the above tests, when no excess of oil shows on the surface of the solution.

The various stages betwen the primary adsorption and the putty-like product represent the gradual thickening of the secondary oil envelope. The strength of the attachment of the secondary film depends largely on the cohesion of the oil itself, the more viscous oils forming more coherent products and the thinner oils less coherent products.

In the test on sized galena crushed to pass an 80 sieve but retained on a 120-mesh sieve (linear inch), it was found that all the oil (5 gms. oleic acid) was adsorbed by 60 gms. of the galena. From these data, the approximate thickness of the oil film at this stage in the adsorption can be calculated. Assuming that the average size of the particles is $\frac{1}{100}$ inch, and that the particles are cubes, the thickness of the oil film would be 0.003 centimetre.

Diagrammatically these successive oil attachments may be shown as follows:—



Diagrammatic representation of oil adsorptions showing the gradual thickening of the secondary film of oil from the primary adsorption to the oily magma. The concentric rings represent the oil films round the mineral particles.

A Primary adsorption—no cohesion of particles.
B Secondary attachments—cohesion.
C Greater cohesion—forming small aggregates.
D Larger aggregates.
E Oily magma—all the interstitial spaces filled with oil.

Analogy of oil adsorptions with water adsorptions.

Oil attachments and water attachments present many similarities. A sulphide carrying 2 or 3 per cent. oil cannot be deprived of its oil by gravity, centrifugal force or other mechanical means. Similarly in the case of wet sand carrying a similar proportion of water, the water cannot be readily separated mechanically. In both cases with the small attachments the laws of gravity are not obeyed. With larger proportions the oil and water will separate out by gravity.

There is also a similarity between the gradual wetting of a finely crushed mineral with water, from the feebly coherent damp mineral to the thick coherent pulp, and the feebly coherent sulphide with a small proportion of oil to the various stages of oily magma. Whether the mineral particles are feebly coherent, due to the presence of a small quantity of water, or when under the surface of a solution the mineral particles are feebly coherent, due to the presence of a small quantity of oil, in both cases the interstitial spaces remain unfilled, in the first case with water and in the second with oil.

In the presence of excess of water and when the mineral has adsorbed as much oil as it will, the interstitial spaces become filled with the respective liquids to form coherent pulp or magma.

Gas attachments.

In my previous paper it was shown that mineral particles would adsorb gases to an extent not previously suspected, and that they would retain the gas adsorptions with such a persistency that they could neither be easily separated by mechanical means nor much affected by gravity and gas expansion. It was also shown that in the case of adsorptions consisting of a mixture of gases, the respective gases may be separated fractionally, the law of gaseous diffusion apparently not being obeyed. With the view of further investigating these gas adsorption phenomena, the following series of experiments were conducted:—

1. Pieces of copper and silver foil were cleaned by boiling in a solution of sodium hydroxide, washing in distilled water and drying. These cleaned pieces of foil and similar uncleaned pieces of foil were then placed in a vacuum flask together with (a) ordinary distilled water, (b) air-free distilled water, (c) ordinary tap water, and subjected to a reduced pressure (26 inches mercury), with the following results:—

	Distilled Water.	Air free Distilled Water.	Tap Water.
Cleaned Foil -	A few bubbles collected on the foil, but the foil does not float.	Very few bubbles formed on the foil; when these were detached no more formed.	Foil floats by the buoyancy of the bubbles that become attached.
Uncleaned Foil -	Many bubbles become attached and the foil floats to the surface.	A few bubbles form on the foil, on detaching which no more formed.	Same as cleaned foil.

On repeating these experiments with the various waters to which a drop of oleic acid had been added and agitated, in all cases the cleaned and uncleaned foil collected gas bubbles. The uncleaned foil floated and remained floating, but the cleaned foil came to the surface repeatedly but did not remain floating. These experiments show that the persistency of the attachment of the gas bubbles is increased when the surface of the foil is contaminated with some oily substance.

2. Six steel needles were boiled in strong sodium hydroxide solution for half an hour, washed with distilled water and allowed to stand in absolute alcohol for half an hour. They were then dried in a desiccator. The needles would not then float on freshly drawn distilled water. When the water was allowed to stand for some time in an evaporating dish, exposed to the air, it was found that they would float.

Another set of needles and pieces of iron wire similarly cleaned would not float at first, but on being kept in a desiccator for two days would float on the surface of distilled water. Similarly some particles of sulphides when washed with alcohol would not float, but on exposure for some time floated. With a preliminary wash in dilute sulphuric acid prior to the other cleansing, the behaviour of the needles and wire was the same as in the case of the other method of cleansing.

This preliminary treatment would remove any oily matter present. When the needles were dried by the aid of a lens and the sun's rays, their floating properties seemed to be improved, If the needles were handled they were found to float much more readily, becoming greasy by contact with the fingers.

These experiments show that perfectly cleaned needles and iron wire will float on the surface of distilled water under the following condition, viz., (a) if the water is allowed to stand for some time in contact with the air, (b) if the needles and wire are allowed to remain exposed to the air for sufficient time.

In the first case probably a layer of fine dust collects on the surface of the water, and in the second case probably the attachment of the air becomes greater after a certain time has elapsed.

3. Cleaned and uncleaned pieces of iron wire on being immersed in a saturated solution of carbon dioxide showed the following results, respectively:—

The cleaned pieces collected very few bubbles on their surface, and the uncleaned pieces were at once covered with a frost of bubbles, and caused to float to the surface. If one of the cleaned pieces is rubbed between the fingers it behaves similarly to the uncleaned wire, and is caused to float. These experiments also show that the gas attachment is enchanced by the presence of some oily material on the surface of the metal.

In order to compare the amount of gas given off from oiled and unoiled surfaces the following test was carried out:—Two cubical pieces of galena of approximately the same size with the same extent of surface exposed were taken, one of which was greased with a very small amount of vaseline. The two pieces of galena were then placed under inverted separating funnels filled with a saturated solution of carbon dioxide and standing in a basin of the same solution. Bubbles of carbon dioxide gas were at once evolved from both pieces of mineral. The bubbles on the oiled fragment grew to a larger size, and were held more tenaciously, but more gas was given off from the unoiled piece, as could be directly measured by the amount of solution displaced in the funnel.

These results show that the oil probably acts as an agent by which the gas bubbles are more tenaciously attached, but that it is the mineral itself which in the first place determines the gas attachment.

4. Some Broken Hill jig tailings were treated with dilute sulphuric acid, and afterwards with water, to separate the whole of the acid. On immersing in a saturated solution of carbon dioxide, bubbles of carbon dioxide gas collected on the sulphide particles, but except in the case of a few garnet particles, they did not collect on the gangue. On dealing similarly with the same tailings without the acid treatment, bubbles of carbon dioxide collected on all the particles, there being no marked distinction between the sulphide particles and the gangue particles. This shows that the acid treatment tends to prevent gas attachment in the case of the gangue particles, while it does not to the same extent similarly prevent gas attachment in the case of the sulphides.

5. Some of the flotation product produced at one of the Broken Hill mines by agitating zinciferous tailings with an acidulated solution, and a small proportion of oleic acid, were collected, as it came to the surface of the solution. This product was collected in a bottle until the bottle was completely filled, thus displacing the air. The bottle was then stoppered, and the gas contained in the flotation product gradually became disengaged as the sulphide settled down. An analysis was made of this disengaged gas, with the following results:—

(1) Analysis of gas disengaged from first sample:—Nitrogen, 72 per cent.; oxygen, 2 per cent.; carbon dioxide, 26 per cent

(2) Analysis of gas disengaged from second sample:—Nitrogen, 82 per cent.; oxygen, 2 per cent.; carbon dioxide, 16 per cent.

These samples were taken at different stages in the concentrating operation.

A sample was also obtained of a flotation product produced by a process using acidulated solution without the addition of oleic acid. The material being treated in this case was Broken Hill slimes, which had been given a slight roast to oxidise the lead sulphide to sulphate in order to prevent the latter floating. An analysis of the disengaged gas from this flotation product (the sample being obtained similarly to the previous flotation product) was as follows:—Nitrogen, 96 per cent.; oxygen, 1 per cent.; carbon dioxide, 4 per cent.

6. The flotation product (mentioned in paragraph 5), in which the zinc concentrate was produced by a process using a dilute acid solution and a small amount of oleic acid, was then treated as follows:—Some of the concentrate, after being deprived of all visible gas by allowing to settle, was placed in a small flask. The flask was nearly filled with the sulphides, and allowed to stand, the sight excess of solution being drawn off. This solution was faintly acid to litmus. The flask was then filled with air-free distilled water, and connected to a vacuum pump, all the connections being also filled with air-free water. On lowering the pressure in the flask the concentrates were noticed to swell up, and completely fill the flask, and an evolution of gas was at once apparent. This gas was collected and analysed. The volume was 1.7 c.c., and consisted of 58.8 per cent. carbon dioxide, 27 per cent. nitrogen, and 14.1 per cent. oxygen. The flask was then immersed in water, which was brought to the boiling point, at the same time continuing the exhaustion by means of the vacuum pump. An additional volume of 8.9 c.c. of gas collected, consisting of almost entirely carbon dioxide. The weight of the concentrates experimented with was 70 gms.

A sample of the second product referred to in paragraph 5 was then taken and similarly treated, except that the wet concentrate was made slightly alkaline with ammonia. On heating and subjecting to reduced pressure as before, the gas collected amounted to 18.5 c.c., practically the whole of which was carbon dioxide, only small quantities of nitrogen and oxygen being present.

These two experiments show that attachments of carbon dioxide still cling to the particles of sulphide on settling beneath the surface of the liquid, and after the visible gas bubbles forming the scum have become disengaged. The analysis of the disengaged gas in the previous tests show that it is mainly composed of nitrogen. Assuming that a proportion of oxygen that would give with the nitrogen found a mixture corresponding to atmospheric air, was originally present, the fact that the gas evolved from the sulphides themselves when subjected to reduced pressure is carbon dioxide, shows that the latter is attached more persistently than is the air.

7. An attempt was then made to collect any gas that might be evolved from dry minerals on subjecting them to a low pressure, in the following manner:—The apparatus was an automatic Toepler pump, designed to collect the gas from the apparatus being exhausted.[1] The mineral to be tested was enclosed in a glass flask, and connected with the pump. The pump was then worked until no more gas could be obtained at ordinary temperature, and the last portions of the gas were collected for analysis. The flask containing the mineral was then heated by immersing in a water bath, containing boiling water, the pump being kept continuously working, and the further quantities of gas obtained were collected and analysed.

At first the pump was used with a desiccating apparatus inserted between the flask containing the mineral and the pump, but as the desiccating agent used (phosphorus pentoxide was first tried, and then dehydrated copper sulphate) in each case apparently adsorbed and retained to a greater or lesser extent portion of the gas first evolved, the pump was finally used without the desiccating apparatus, the minerals being previously dried as far as as possible by keeping them in a desiccator for several days. The vacuum obtained under these conditions was, however, not so complete as when the desiccating apparatus was used.

Table A shows the results of these tests. Column III. of this table shows the composition of the last portions of gas

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[1] "An Automatic Toepler Pump designed to collect the gas from the apparatus being exhausted." Bertram D. Steele, D.Sc., Proc. of Physical Society, London. Vol. xxii.; also Phil. Mag., June, 1910.

TABLE A.—*Analysis of gas obtained from dry minerals in vacuo.*

Mineral taken.	Weight in gms.	Last portion of gas obtained without heating (unit = .0033 c.c.)				Additional gas obtained on heating (unit = .0033 c.c.)			
Chalcopyrite (freshly crushed dry lump)	100	25.6	units with the composition of	CO_2	23.8	23.9	units composed of	CO_2	81.2
				*N	66.4			*N	17.5
				O	9.7			O	1.2
Broken Hill zinciferous tailings	100	11.7		CO_2	8.5	20.1		CO_2	67.6†
				N				N	28.8
				O				O	3.4
Zinc concentrates (obtained by oil and acid flotation process)	67	37.4		CO_2	0.2	4.7		CO_2	68 †
								N	29.8
								O	2.1
Broken Hill slimes	100	30.1		CO_2	64.1	227		CO_2	99 †
				N	31.8				
				O	3.9				
Broken Hill slimes (from another mine)	58	8.4		CO_2	11.9	126		CO_2	85 †
				N	72.6				
				O	15.4				
Crystalline galena	162	60		CO_2	5.1	79.2		CO_2	69.4
								N	25.7
								O	4.8
Rhodomite (cont. a little zinc blende and galena)	98	16 8		CO_2	5.3	19.8		CO_2	29.8
				N	83.9			N	63.6
				O	11.9			O	6.6
Quartz sand	77	24.2		CO_2	0.8	4.1		CO_2	4.8
								N	73.1
								O	21.9
Cerussite	39	16.5		CO_2	5.4	25.6		CO_2	7.7†
Calcite	16	53.3		CO_2	2.2	2.5		CO_2	20
				N	77.8				
				O	19.8				

* The residual gas remaining after absorbing the CO_2 and oxygen is taken as being nitrogen in these analyses.

† Dried in desiccator.

obtained before the mineral was heated. As the whole of the gas before heating was not collected, these figures have no relation with the whole of the gas obtained, but simply relate to a final product, the quantity and composition of which depends upon the stage of exhaustion reached when it was collected. Column IV. shows not only the composition, but also the total quantities of the gas obtained from the mineral under these conditions. The volume occupied by the different minerals was approximately the same, except in the case of calcite and cerussite.

Before each test on the different minerals, the pump was carefully exhausted. As a rule the residual gas from the pump gave negative results—i.e., it was of the same composition as atmospheric air. Some of the blank tests, however, showed the presence of small quantities of carbon dioxide, with a higher proportion of residual gas, after absorbing the oxygen, than would be the case if the gas had been atmospheric air. The blank tests were tried, both in the cold and in heating the empty flask in boiling water. The deviation from the composition of atmospheric air in some of the blank tests may be accounted for by the retention of some of the gas from a previous experiment, on the glass walls of the apparatus or by the mercury itself.

Description of gas analysis apparatus.[1]

The gases were analysed in a Bonnier and Mangin gas apparatus (shown in the adjoining text figure), capable of analysing with accuracy very small volumes of gas. The capacity of the apparatus is approximately 0.2 c.c. As can be seen from the reproduced photograph, it consists of a metal cylinder A, from which the mercury can be forced out, or drawn in, from the glass reservoir F, by way of the graduated capillary tube C, and through the large bulb of the capillary tube at B. The movement of the mercury is controlled by means of the small hand wheel E, which moves, on turning, a screw piston, either backwards or forwards, as desired, in the cylinder A. The capillary tube C enters the reservoir F through the base, and rises to a point about level with the bottom of the enlarged diameter of the reservoir at F.

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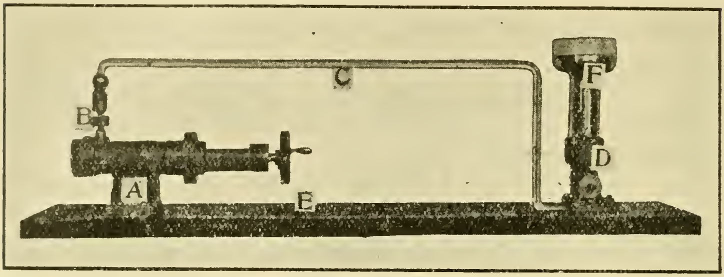
[1] This gas apparatus was kindly lent by Professor Ewart, of the Botanical Department.



The sample of gas collected from the Toepler pump over mercury in a small test tube is introduced by inserting the test tube over the end of the capillary at F, which is under mercury. The test tube is pushed down until the end of the capillary is in the gas above the mercury. The gas is then drawn into the capillary by working the hand wheel E. The volume of gas is measured on the scale of the capillary tube C. This tube is divided into 60 divisions, subdivided into tenths. Sixty divisions on the scale = 0.2 c.c. The absorbing reagent, such as caustic potash or alkaline pyrogallol, is introduced in the same manner as the sample of gas, and is brought into contact with the latter by turning the small wheel until the liquid reaches the bulb B, after allowing time for the absorption to take place, the gas is pushed back by the mercury and the piston, and the volume again read, the diminution, if any, being noted. D is a screw tap to withdraw the mercury from F.

The results of these tests and analyses show that from the sulphides and material containing sulphides, such as the Broken Hill tailings and slimes, as a rule more gas was obtained than from the calcite and quartz. This gas consisted mainly of carbon dioxide. The residual gas, after absorbing the carbon dioxide and oxygen, was largely in excess of the proportion of nitrogen in atmospheric air, and may contain hydrogen or an excess of argon. That the carbon dioxide in these tests is not derived from the decomposition of carbonates during the experiment is shown by the negative results shown by cerussite and calcite.

These results indicate that there is apparently a concentration or condensation of gas consisting mainly of carbon dioxide on the surface of the sulphides, and to a much less extent on the other minerals tried. This gas is held persistently, and does not obey the laws of gaseous diffusion, and may therefore be present in the liquid form. This is indicated by the fact that it is the more easily condensed gas, that is the more persistently attached. The fact that finely divided material in the form of slimes will attach more gas than similar material in a coarser state, indicates that the action is a surface action. It may be akin to the action of charcoal, which will absorb large volumes of the more readily condensible gases as carbon dioxide, sulphur dioxide, and ammonia. It is known that water vapour will cling most persistently to some surfaces even at high temperatures.[1]

In a previous paper already referred to, the writer found that carbon dioxide was obtained from all the sulphides tried by the aid of heat and exhaustion in the presence of water. It is probable that the gas film can only be expanded for removal in appreciable quantities in the presence of water, and that exhaustion in the dry state does not remove all the gas present. The film can be removed by solvents.

The thickness of the film is probably analogous to the thickness of adsorbed oil and adsorbed water films.

Analogy of gas adsorptions with oil adsorptions.

When an excess of oil is attached to a sulphide it can be separated to some extent by stirring or by pressure. Similarly if a sulphide flotation product, which was floated by gas, is stirred, a large proportion of the excess gas is given off. This can be seen by the larger bubbles bursting, and the shrinkage in volume of the flotation product on standing. If a flask is completely filled with some of the flotation product, and the flask is then stoppered, on standing it will be noticed that the scum occupies a lesser volume, partly due to cooling and partly to the bursting of the bubbles and disengagement of the gases. For instance, in a large Winchester quart bottle originally completely filled with the flotation product, on standing the sulphides only occupied about 2 inches on the bottom of the bottle. The remainder of the space (6 inches), except for 5 inches of solution, was occupied by the disengaged gases.

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[1] "Adsorption of water vapour by quartz." Journal of Phys. Chem., vol. ix., 1905, page 617.

The different stages of oil and gas adsorptions are analogous to a certain extent. In the case of the latter, where there is insufficient gas to buoy the mineral to the surface, but aggregates are formed (such as are brought about by weak chlorine and nitric acid solutions in the cold), there is a similarity to the aggregation stage in oil adsorptions, where a thin secondary film of oil is attached to the primary film. In the case of gaseous aggregations, flotation can be brought about by increasing the amount of attached gas—e.g., by adding a saturated solution of carbon dioxide, the bubbles of the latter gas becoming attached to the aggregates, and buoy them to the surface.

Thus the stages in producing flotation of a sulphide by oil without the aid of gas are:—

(1) Primary adsorption film.

(2) Secondary attachments, which will form aggregates.

(3) Oily magna formed by excess attachments.

(4) Oil sufficient to bring about the production of magna of such a specific gravity as will float in water.

Similarly the stages gone through in bringing about the flotation of a sulphide with gas are:—

(1) Primary adsorption film.

(2) Aggregates formed by secondary attachments.

(3) Fairly stable aggregates which float by the aid of heat or reduced pressure.

(4) A scum or froth containing an excess of gas, which is mostly disengaged by agitation, after buoying the aggregates to the surface.

Flotation experiments with varying amounts of oil and acid.

The following is a series of flotation experiments carried out with a view to obtaining some data as to the effect of acid on the subsequent flotation product produced when an oil is used, the results of which are given in Table B.

The tests were carried out in an enamelled pot, with a stirring apparatus attached. The pot was heated from below by a gas burner. The method of effecting the flotation was to add the various materials taken in the tests to the 1400 c.c. of water in the pot, and to gradually heat the mixture, at the same time keeping the agitating propeller working continuously. On ceasing the agitation for a few minutes to let the flotation product come to the surface, this latter was skimmed off with a wire gauze strainer. After each skimming another period of agitation was given, and in some cases, as noted in the table, more acid was added, and the flotation product re-skimmed. The tailings called No. 1 have a gangue consisting mainly of quartz and rhodonite, and those called No. 2 have a more calcitic gangue. In the tests numbered 1-10 inclusive, the tailings with the rhodonite gangue were used, and in tests 11-14 inclusive the tailings with the calcite gangue were used. Except where otherwise stated, 1400 c.c. of water were used in each experiment.

The results of the experiments show that (1) without the addition of acid the flotation product produced by oil contains much gangue material, and (2) that the addition of acid up to a certain point decreases the amount of gangue in the flotation product.

This series of experiments was carried out in conjunction with Mr. Donald Clark, late lecturer in Metallurgy at the University.

TABLE B.—*Flotation Experiments.*

No.	Materials taken for test.	Weight of Flotation product in gms.	Containing % Zn.	Containing % insol. gangue.	Weight of residues produced.	Containing % Zn.	Containing % insol. gangue.	Remarks.
1	No. 1 Broken Hill tailings 400 gms. Oleic Acid 0.8 gm. Water 1400 c.c	272	22.4	46.6	119	14.3	39.6	Heated to near boiling point. Agitated repeatedly and skimmed.
2	Tailings 400 gms. H_2SO_4, three lots of 8 c.c. each added	129	49.4	1.4	236	6.3	71.4	First 8 c.c. of acid gave little scum, 2nd copious, 3rd poor.
3	Tailings 400 gms. H_2SO_4 5 c.c. Oleic Acid 0.8 gm.	93	46.3	1.1	292	11.0	60	Flotation distinct at 80° C.
4	Tailings 400 gms. H_2SO_4 10 c.c. Oleic Acid 0.8 gm.	105	46.8	1.2	276	9.8	69	
5	Tailings 400 gms. H_2SO_4 15 c.c. Oleic Acid 0.8 gm.	109	48.7	1.4	261	8.3	64.6	
6	Tailings 400 gms. H_2SO_4 1 gm. Oleic Acid 0.4 gms.	37.5	48	1.8	354	1.9	49.2	Skimmed and stirred about 20 times.
7	Tailings 400 gms. H_2SO_4 2 gms. Oleic Acid 0.4 gm.	84.5	33	23.2	308.5	17.5	53.6	Skimmed and stirred about 20 times.
8	Same as No. 7 with H_2SO_4 4 gms.	78	40.5	3.2	312	14.3	58	
9	Same as No. 7 with H_2SO_4 8 gms.	77	47.5	1.2	308	12.7		
10	Same as No. 7 with H_2SO_4 12 gms.	80	47.4	1.0	295	12.4	58.6	
11	No. 2 Broken Hill Tailings 400 gms. H_2SO_4 4 c.c. Oleic Acid 0.4 gms.	27.5	36.8	9.0	365	11.4	54.6	
12	Same as No. 11 with H_2SO_4 8 c.c.	36	43.7	4.8	351	9.7	62.4	
13	Same as No. 11 with H_2SO_4 12c.c.	78	45.3	2.2	298	5.0	69.6	
14	Same as No. 11 with H_2SO_4 16 c.c.	78.5	45.4	0.8	311	4.6	67	

TABLE B.—(*Continued*).

No.	Materials taken for test.	Weight of Flotation product in gms.	Containing		Weight of residue produced.	Containing		Remarks.
			% Zn.	% insol. gangue.		% Zn.	% insol. gangue.	
15—	Broken Hill Slimes 400 gms. water	122	31.5	11.0	277	15.1	34.2	
	1500 c.c. H_2SO_4 7 gms. - -							
	Oleic Acid 0 8 gm. - - -							
16—	Same as No 15 but with 14 gms. -	217	32.2	9.0	166	4.8	54.6	Skimmed about 30 times.
	H_2SO_4 - - - - -							
17—	Broken Hill tailings 340 gms. - -	1st 38.5	42.9	2.8	262	8.4	64.8	The third addition of 6.4 c.c. produced no more flotation.
	,, ,, slimes 60 gms. - -	2nd 72	51.2	1.0				
	H_2SO_4 19.2 c.c. added in 3 lots							
	of 6.4 c.c. each - - - -							
18—	Same as No. 17 but with Oleic Acid	(1) 75.5	39.2	8.6	268	5.8	60.4	
	0.4 gms. H_2SO_4 added in 3 lots	(2) 17.5	46.3	2.2				
	of 6 c.c. each - - - -	(3) 7.5	45.7	2.4				
19	Broken Hill tailings 340 gms. -	(1) 122.5	38.2	10.8	230	18.8	44.6	
	,, ,, slimes 60 gms. - -	(2) 25	47.9	5.1				
	Fuel oil 1.5 gms. - - -	(3) none						
	H_2SO_4 added in three lots of							
	6 c.c. each - - - -	(1) 7.2	35.4	10.6	330	8.3	63.8	
20—	Broken Hill tailings 340 gms. +							
	slimes 60 gms. - - - -	(2) 22.7	44.9	2.2				
	Hydrocarbon oil 0.8 gms. H_2SO_4							
	added = 20 c.c. - - -	(3) 16.8	45.0	1.4				
	in five lots of 4 c.c. each - -	(4) 8.5	48.4	1.2				
		(5) none						
21—	Broken Hill Crude ore 200 gms. -	6.4	37.7	4.4	128	6.8	63.2	
	Oleic Acid 0.4 gm. - - -							
	H_2SO_4 2.4 c.c. - - - -							
22—	Broken Hill Crude ore 200 gms. -	(1) 57.5	20.6	29.2	73	10.9	56	1st float 6 skims. Heated gradually to 80° C;
	Oleic Acid 0.4 gm. - - -	(2) 69.5	20.8	30.6				2nd float 15 skims. 20 minutes agitation.

The separation of intimately mixed lead and zinc sulphides.

One of the problems to be overcome in the treatment of lead zinc ores is the separation of the lead and zinc sulphides into suitable products for subsequent. treatment. For instance the concentrates from the different flotation processes working at Broken Hill contain varying amounts of zinc blende and galena. When these concentrates have been produced from fairly coarse tailings, a fair separation of the galena and blende can be made by the difference in gravity of the minerals, by such appliances as vanners and concentrating tables. However, with concentrates produced from slime, the separation of the lead and zinc sulphides becomes very much more difficult, and cannot be efficiently effected by gravity concentration. One method that has been used is as follows:—The mixed sulphides are given an oxidising roast at a low temperature, which hardly affects the zinc blende, but which causes a "coat" of lead sulphate to form on the surface of the lead sulphide particles. The product is then treated by a flotation process, the zinc blende floating and the sulphated galena behaving similarly to gangue, and not floating. This is known as the Horwood process.[1]

The writer tried various chemical solutions for the purpose of preventing the flotation of the galena in such mixtures of sulphides. Some fairly good results were obtained by using a solution of ferric chloride. The action of the ferric chloride solution is to cause a permanent and not easily detached coat on the particles of galena. The zinc blende is unaffected by the solution. This white coat formed on the surface of the galena particles consists of sulphur and lead chloride. When the ferric chloride solution is used hot, the action is quicker. Some oxide of iron, thrown out of solution, is sometimes present in the substance forming the coat when the ferric chloride is allowed to stand on the mixed sulphides for some time. Any lead being dissolved is re-precipitated by the sulphuric acid in the subsequent flotation operations. The ferric chloride becomes reduced to the ferrous state, and can be readily regenerated if required.

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[1] "Treatment of mixed sulphides by the Horwood process." E. J. Horwood, Proc. Aust. Institute Mining Engineers, June, 1911.

The results of some small tests on various ores and products are as follow:—

Details of ferric chloride tests.

No. 1.—Concentrates produced from an acid flotation on Broken Hill tailings, ground to pass 80 mesh sieve.

Fifty gms. taken and kept in suspension for half an hour, with 200 c.c. water containing 10 gms. $FeCl_3$, and allowed to stand 18 hours. Refloated with H_2SO_4 and a small amount of oleic acid.

	Zn. p.c.	Pb. p.c.
Zinc product, 45 gms., floated - -	51.0	6.2
Lead product, 5 gms., not floated -	7.4	47.6

No. 2.—Concentrates produced from an acid flotation on Broken Hill slimes. 200 gms. of the mixed concentrate kept in suspension for 6 hours, with 300 c.c. of a 10 per cent. $FeCl_3$ solution.

Refloated with sulphuric acid and a small amount of oleic acid.

	Zn. p.c.	Pb. p.c.
Zinc product, 169 gms. - - -	51.8	5.3
Lead product, 28 gms. - - -	16.7	38.1

No. 3.—Concentrates produced from an acid flotation on another sample of Broken Hill slimes. 100 gms. concentrates taken and stood for 24 hours with 300 c.c. 10 per cent $Fe Cl_3$ solution.

Refloated with sulphuric and small amount of oleic acid.

	p.c. Zn.	p.c. Pb.	oz. ag.
Zinc product, 67 gms. - -	48.5	8.2	25.25
Lead product, 31.5 gms. -	7.7	46.8	13.25

No. 4.—Crude zinc lead ore from Tasmania. 200 gms. ore kept in suspension for three-quarters hour and then let stand with a 3 per cent. $FeCl_3$ solution.

Floated the mixed sulphides with a small quantity of H_2SO_4.

	p.c. Zn.	p.c. Pb.	ozs. per ton Ag.
Zinc product, 77 p.c. by weight	44.8	5.7	22.6
Lead product, 33 p.c. by weight	10.8	41.3	9.4

No doubt these results could be greatly improved upon under better working conditions and by working on a larger scale. For instance, when working with a deeper flotation vessel, the lighter particles in the lead product have a better opportunity to settle, and are not so likely to be carried over mechanically with the flotation product. On refloating the zinc product, more lead can be separated as an unfloated residue.

The writer wishes to acknowledge the suggestions and advice in this work by Messrs. Donald Clark, A. J. Higgin and T. G. Greenway.

[Proc. Roy. Soc, Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXIII.—*The Anatomy of the Slug, Cystopelta petterdi, var. purpurea, var. nov.*

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(With Plates LXIV-LXIX.).

[Read 14th December, 1911.].

Since the description given by Mr. Hedley in 1890 no further work has been done, so far as I can discover, on *Cystopelta petterdi*. Professor Spencer and Mr. Hedley therefore suggested that I should give a fuller acount of the anatomy of this animal. In the Biological Department of the Melbourne University were some preserved specimens, some of which came from Beech Forest, Victoria, and were preserved in spirit, and so contracted as to be of no use for external description or dissection. These were used in sections, being stained with acetic acid alum carmine. The rest came from Fernshawe, Victoria, and were preserved in formalin. Later I found two living specimens at Narbethong, Victoria. These I used for dissection and external description.

Professor Tate gave a short description of *Cystopelta petterdi* in the Report of the Royal Society of Tasmania, 1880. A description and drawing of the animal has also been given by Mr. C. Hedley in the Proceedings of the Linnean Society of New South Wales, 1890.

External Features and General Description. (Fig I.)

The animal is small and slug-like, with its organs drawn into a dorsal hump as in snails, but no spiral twisting is visible from the exterior. The hump is very large, extending from just behind the reproductive opening anteriorly, to overhang about half the free portion of the foot posteriorly. In colouring, my specimens resemble neither those described by Mr. Hedley nor those described by Professor Tate. The two living specimens were pale grey, with two short darker lines on either side of the posterior end of the foot, and on the dorsal surface of the shield a few bright violet spots. At the posterior end the foot is divided into three lobes, where the mucous pore is situated, and from this a pedal groove runs along either side of the foot to the anterior end. The whole of the under-surface of these grooves is ciliated, the cilia extending right round the surface of the foot. (Figs. 5 to 12.) The pulmonary opening cuts well into the edge of the shield; the reproductive opening is situated just below the right superior tentacle, and slightly posterior to it. There is no trace of a shell. The alimentary canal, liver, kidney, heart, and some of the reproductive organs are all drawn up, forming a visceral hump beneath the shield; none of the organs extending to the posterior end of the foot, as in the *Limacidae.* I took the following measurements from a living specimen:—Length of foot, 19.5 mm.; length of shield, 16.7 mm.; depth of shield, 3.75 mm. The dorsal wall of the hump is thick; the anterior portion, being very vascular, forms the respiratory organ, while the sides of the under wall at its posterior end are very thin, the organs being slightly visible through it.

Organs of the Mantle Cavity.

The *heart* occupies the left ventral corner of the mantle cavity, being covered dorsally and on the right side by the kidney. The ventrice (Figs. 4, 7, 8) is oval in shape, and has numerous muscles running in every direction through its walls. The auricle (Fig. 6) is much smaller than the ventricle, and very slightly muscular. The pericardium (Figs. 4, 6, 7, 8) lies close to the heart, except on the left side, where it is nearer the body wall, and on the right side at the region of the reno-pericardial opening (Fig. 4). It is a delicate, but very definite membrane, the nuclei in its cells showing up very plainly in sections. I was unable to determine the course of the blood vessels, excepting the main ones, which do not seem to differ at all from those of other forms. One vessel (Fig. 4) runs up from the ventricle through the reno-pericardial canal.

The *kidney* (Figs. 4, 6, 7, 8, 13) is a large mass forming a spongework occupying the greater part of the mantle cavity. It consists of masses of cells and tubules, the tubules being in greater number and more conspicuous on the dorsal surface. (Fig. 13). These finally open into the ureter, which runs along the dorsal surface of the kidney to the right side, where it descends and opens to the exterior (Figs. 7, 13) just in front of the anus. Among the cells we can distinguish three kinds—(1) small granular cells, (2) larger clear cells with distinct nuclei, (3) cells which are stained brown and which may not be a distinct kind from the small granular cells, the difference in staining being perhaps due to the presence of inorganic material.

The *Renopericardial canal* (Fig. 4) is more difficult to make out than in other forms, probably owing to the irregular shape of the kidney and to the presence of a blood vessel in it. In all the three series of transverse sections I examined, it appears to be double at its cardiac end, but the lower branch ends blindly, the upper alone really forming a renopericardial canal. The figure of the section given recalls the figure in J. T. Cunningham's paper on "The Renal Organs of Patella."[1] The similarity suggests to me that the lower may be a vestigial second renopericardial canal.

The Reproductive System.

In the description given by Mr. Hedley he says: "The genital system appears much contorted at its orifice, after which it divides into three portions—the duct of the genital bladder, which is rather short, twisted, and continuing after reaching the genital bladder, is again expanded into a second sac; the penis, stout and pyriform, invaginated upon itself and produced into a slender flagellum; and the vagina, long and slender, and also invaginated upon itself." The following is a description of the reproductive system as made out from specimens I have examined, which differ, as will be seen, in a few points from those examined by Mr. Hedley.

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[1] Q.J.M.S., vol. xxiii.

The *Hermaphrodite gland* (Figs. 2, 10, 11, 12) is comparatively large. It is situated on the right side of the visceral mass posterior to the mantle cavity, being surrounded on its left and partly on its ventral sides by the liver. It is a compact gland made up of a number of lobules; the male elements are arranged in groups towards the centre of each lobule, and the female elements are arranged round these.

The *Hermaphrodite duct* (Figs. 2, 11, 12) leaves the hermaphrodite gland from about its centre and runs in a sinuous course to the albumen gland, entering the latter along the right side towards the posterior end. It is a simple, thin-walled tube.

The *Albumen gland* (Figs. 2, 9, 10, and 11) is not so compact as the hermaphrodite gland. It consists of tubules and lobules. Towards its anterior end it really surrounds the common duct, so that it is only in section that the boundary of duct and gland can be seen, and then with difficulty, owing to the large number of tubules in the gland.

The *Common duct* (Figs. 2, 9, 10) is very short, and divides almost before leaving the albumen gland into oviduct and vas deferens.

The *Vas deferens* (Figs. 2, 7, 8, 9, 15) is a long narrow duct, ciliated towards its anterior end. It leaves the common duct on the left side and runs up, behind, round, and across the amatorial organ, across the oviduct, and widens to end in the penis.

The *Penis* (Figs. 2, 7, 8) is a large protrusible muscular organ, with the retractor muscle attached towards its posterior end; just behind this is a large globular swollen portion. The penis leads into a common genital atrium.

The *Oviduct* (Figs. 2, 6, 7, 8, 15) is a long tube leaving the common duct on its right side, and running fairly straight to the anterior end, where its walls become swollen and invaginated just before its opening into its common genital atrium.

The *Amatorial organ* (Figs. 2, 6, 7, 8, 14). What Mr. Hedley describes as "the duct of the genital bladder . . . expanded into a second sac," I take to be the amatorial organ. It is a large swollen body, running right back to the level of the albumen gland, to end blindly at that region. It has very thick walls beset with numerous glands, which all open into a central lumen. The organ opens anteriorly into the common genital atrium.

The *Common genital atrium* (Figs. 2, 5, 6, 7, 8) receives the openings of the penis, the oviduct, and the amatorial organ. It opens to the exterior by the reproductive opening situated just slightly posterior and ventral to the right superior tentacle (Fig. 1). The penis can be protruded through the atrium, and the reproductive opening to the exterior.

The Alimentary System.

The *Mouth* is situated on the ventral surface, and leads into the buccal cavity. The buccal mass occupies most of the anterior part of the head (Fig. 5). The buccal bulb is lined by an epithelium of columnar cells, with very distinct nuclei, the walls are very muscular, the two lateral ones extremely so. The jaw has been described by Mr. Hedley. In section it is seen to consist of a layer of chitin, which stains deeply, with a serrated free edge; the serrations all pointing in the same direction. (Fig. 5.) Under this chitinous layer is a layer of oblong cells with large granular nuclei, the nuclei all being arranged at the ends of the cells away from the chitinous layer.

The *Radula* (Fig. 6) is so deeply stained in my sections that nothing can be made out of the teeth, but under them is a very clear epithelium, composed of cells with large granular nuclei, and under this a pad of muscle fibres and connective tissue. The radula consists of about ninety-six rows of very fine teeth. The shapes of these teeth were distinguished from preparations of the radula both unstained and stained with picro-carmine.

The *Rachidian* (Fig. 3) is tricuspid, the three cusps twisting around each other in such a manner that it is only by careful focussing that the shape can be seen. The base is roughly conoid.

The shapes of the laterals and marginals which gradually merge into one another can be best understood by reference to the figure (Fig. 3), which represents some of them from a lateral view, taken from a teased radula and arranged as far as possible in order.

The *Oesophagus* (Figs. 5. to 10) commences as a fairly straight wide ciliated tube compressed dorso-vertically. This portion of it receives the ducts from the salivary glands; it then becomes narrower (Figs. 7, 8, 9) and continues as a narrow tube till it reaches almost the middle of the visceral mass, where it widens to enter the stomach (Fig. 10). It is lined by a mucous epithelium of large, clear cells, with granular nuclei, the nuclei being situated at the ends of the cells away from the lumen of the tube. This epithelium, which is thrown into folds, forms the greater part of the walls of the tube (Fig. 17).

The *Stomach* (Figs. 9, 10, 11, 12, 17) is a very large dilated sac on the left side of the posterior end of the visceral mass. It is almost completely surrounded by the liver. Its walls, towards its anterior end, consist of a thin muscular layer, lined by a simple epithelium, the cells of which are not well defined, and the nuclei are indistinct. The oesophagus enters the stomach ventrally at its anterior end (Fig. 10), and here the lining epithelium is slightly thrown into folds, and the cells with their nuclei are more definite. At the posterior end (Figs. 11 and 12) the walls become thickened and nuclei of the lining membrane more definite, the membrane itself forming folds. This posterior part is probably the true stomach, the anterior part representing a crop. Under a high power (Fig. 17) the membrane is seen to consist of long narrow cells with large granular nuclei. Also there are other cells which are vacuolated. Outside the membrane is a muscular layer. The stomach receives the hepatic ducts.

The stomach opens into the *Intestine* which runs up between the liver and the hermaphrodite gland (Figs. 9, 10, 11, 12, 17) along the dorsal surface of the visceral hump, dorsal to the hermaphrodite gland, and opens into the rectum (Figs. 9 and 10), which runs forward between the hermaphrodite gland and the body-wall to open to the exterior, just behind the opening of the ureter, by the pulmonary opening. The lining membrane of the intestine (Fig. 17) is very like that of the stomach, but there are no vacuoles nor a definite muscle larger in the intestine. The intestine is smaller in diameter than the stomach, but it dilates to form the rectum.

The *Salivary glands* (Figs. 8, 9, 10) lie on either side of the oesophagus, at the anterior end dorsal to it, but further back they surround it. In them can be distinguished two kinds of cells, very fine granular cells, with large granular nuclei and distinct nucleoli, some of which cells are vacuolated, and smaller cells, which stain more deeply. From each gland a duct runs up to open into the oesophagus (Fig. 5) just before it leaves the buccal mass.

The *Liver* (Figs. 8 to 12) is a large organ situated about the middle of the visceral mass, and more or less surrounding the hermaphrodite and albumen glands, the stomach and the intestine. It consists of a large number of caeca bound together by connective tissue. The lumina of the caeca are bounded by cells, which are probably secretory, and contain masses of small brown-stained particles.

The Nervous System.

There do not seem to be any notable differences in the structure of the nervous system of this species from that of other forms.

The *Cerebral ganglia* (Figs. 7 and 8) are two large pyriform masses lying on either side of the oesophagus, at their posterior ends swelling out dorsally to lie right across it, so as to form, with the pedal and viscero pleural ganglia, a collar round the oesophagus (Fig. 7), The cerebral commissure (Fig. 7) is short, connecting the two ganglia across the oesophagus. Anteriorly two short buccal nerves run forwards, and just beside the salivary ducts, from the two buccal ganglia (Fig. 6), which are connected by the buccal commissure. Nerves from the buccal ganglia supply the buccal mass. The tentacular nerves are very large, and arise from the outer sides of the cerebral ganglia towards their anterior ends. (Fig. 7.) Labial nerves also arise from the cerebral ganglia, and far forward give rise to labial ganglia.

The *Pedal* and *Visceropleural ganglia* (Figs. 7 and 8) lie very close together, forming the sub-oesophageal ganglionic mass. The viscero-pleural ganglia are situated slightly dorso-lateral to the pedal ganglia. The ganglia are connected by commissures, and also there are the cerebro-pedal, cerebro-visceral, etc., connectives, as in other forms. From the pedal ganglia a number of nerves pass to the foot, and from the viscero-pleural ganglia nerves pass to the body wall and to the different viscera. The ganglia consist of nerve fibres in the centre, and surrounding these the typical ganglionic cells, large and granular, with branching processes and very distinct nuclei, and smaller granular nucleated cells. The whole ganglion is bounded by an outer fibrous membrane.

Sense Organs.

These are the eyes, otocysts and sense papillae.

The *Eyes* do not differ from those of other forms.

The *Otocysts* (Figs. 8 and 16) are two semi-lunar sacs situated on the outer dorsal sides of the pedal ganglia. The walls of these sacs appear to be formed by a thickening of the outer membrane of the ganglia. In the walls are rounded granular cells. The cavities contain minute particles, which I take to be the calcareous otoliths, although I could not prove them to be calcareous, probably owing to the acid I had used in staining my specimens. In the inner corner of each otocyst is a minute patch of cilia. The auditory nerves run down beside the pleural ganglia to enter the posterior ends of the otocysts, having their origin in the cerebral ganglia.

Pedal Gland.

Pedal gland (Figs. 5 to 12). This is a large gland extending down almost the entire length of the foot, becoming larger at its anterior and posterior ends, the median portion being compressed by the visceral mass. It has a ciliated opening anteriorly (Fig. 5) in the mid-line between the snout and anterior part of the foot, and a posterior opening by the caudal mucous pore. It consists of large, slightly granular gland-cells, with large rounded granular nuclei and distinct nucleoli, connective tissue and small granular cells. A great deal of mucus is present, and takes the stain very readily. The median walls of the gland surround a space which is ciliated, more particularly the anterior portion. This acts as a duct for the gland. Besides this large pedal gland the whole surface of the animal is covered with unicellular glands, many of which contain the deeply-stained mucus.

Cystopelta at one time was placed in the *Limacidae.* Later Tryon put in the *Tebennophoridae,* while Mr. Hedley's classification is :—Family, Zonitidae; Sub-family, Helicarionnae; Genus, Cystopelta.

The few differences I have noted in the specimens described by Professor Tate, Mr. Hedley and myself incline me to the belief suggested by Mr. Hedley in his paper, that the Tasmanian, Victorian and New South Wales forms may in reality be different species, but until they can be fully worked I prefer to look on the Victorian form as a new variety which I name "purpurea."

I now wish to thank Professor Spencer, under whom this work has been carried out, for his advice and assistance; also Mr. Hedley, Dr. Hall and others who at times have helped me out of difficulties.

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EXPLANATION OF PLATES.

In all figures:—

A.G.	Albumen gland.
A.O.	Amatory organ.
A.O.O.	Opening of the amatory organ into the genital atrium.
AUR.	Auricle.
B.C.	Buccal cavity.
B.G.	Buccal ganglia.
B.M.	Buccal mass.
B.V.	Blood vessel.
C.	Cilia.

C.D.	Common duct.
C.G.	Cerebral ganglia.
C.G.A.	Common genital atrium.
E.	Eye.
F.	Foot.
Gl.	Glands.
H.D.	Hermaphrodite duct.
H.G.	Hermaphrodite gland.
I.	Intestine.
J.	Jaw.
K.	Kidney.
L.	Liver.
L.D.	Liver duct.
L.T.	Lateral tooth.
LU.	Lumen.
M.	Mouth.
M.C.	Mantle cavity.
MG.	Marginal tooth.
MUS.	Muscle.
N.	Nerve.
O.	Oesophagus.
OD.	Oviduct.
OL.	Otoliths.
OT.	Otocyst.
P.	Penis.
P.C.	Pericardium.
P.G.	Pedal ganglia.
P.Gl.	Pedal gland.
P.Gl.D.	Duct of pedal gland.
P.Gl.O.	Opening of pedal gland.
P.Gr.	Pedal groove
P.O.	Pulmonary opening.
R.	Rectum.
RAC.	Rachidian.
RAD.	Radula.
R.M.	Retractor muscle.
R.O.	Reproductive opening.
R.P.C.	Renopericardial canal.
S.	Stomach.

S.D.	Salivary duct.
S.D.O.	Opening of salivary duct into oesophagus.
S.G.	Salivary gland.
SP.	Spermatozoa.
T.I.	Inferior tentacle.
T.S.	Superior tentacle.
U.	Ureter.
U.M.G.	Unicellular mucous gland.
U.O.	Opening of ureter.
V.	Ventricle.
VAC.	Vacuole.
V.D.	Vas deferens.
V.H.	Visceral hump.
V.P.G.	Visceropleural ganglia.

Fig. 1. Whole animal.
Fig. 2. Reproductive system.
Fig. 3. Teeth.
Fig. 4. Reno-pericardial canal.

Figs. 5 to 12 (inclusive) are typical transverse sections taken in order, Fig. 5 being most anterior.

Fig. 5. Section through buccal mass. Shows opening of salivary ducts into oesophagus, and the anterior opening of the pedal gland and posterior part of reproductive opening.

Fig. 6 shows the opening of the amatory organ into the common genital atrium, and the invagination of the oviduct.

Fig. 7. Section at level of the pulmonary opening, shows the relative positions of the chief nerve ganglia. The tentacular nerve crossing to the tentacle.

Fig. 8 shows the otocysts *in situ* on the pedal ganglia.

Fig. 9 shows the oesophagus surrounded by the salivary glands; the complicated nature of the common duct; the rectum just posterior to its opening to the exterior; and the albumen gland free from the common duct.

Fig. 10. The manner in which the common duct becomes, as it were, part of the albumen gland; position of the salivary glands; opening of oesophagus into stomach.

Fig. 11. Section just after the foot becomes free. Shows hermaphrodite gland with spermatozoa very distinct; hermaphrodite duct entering the albumen gland; and portion of stomach where its mucous lining is thrown into folds.

Fig. 12. Hermaphrodite duct leaving hermaphrodite gland.

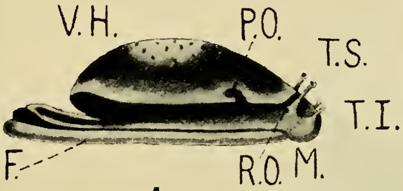
Fig. 13. Ureter at point of opening into the mantle cavity.

Fig. 14. Amatory organ, showing its glandular walls.

Fig. 15. Vas deferens (ciliated) and oviduct.

Fig. 16. Otocyst.

Fig. 17. High power drawing of stomach, intestine, rectum and oesophagus.



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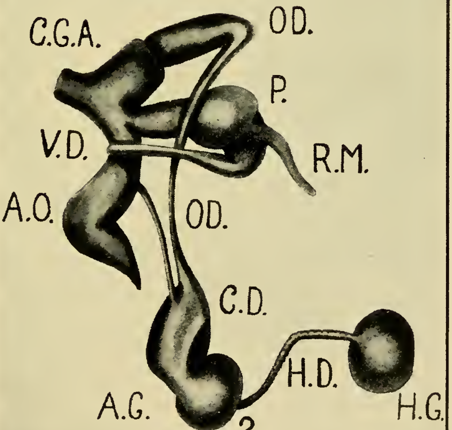

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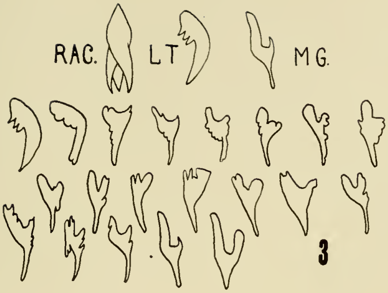

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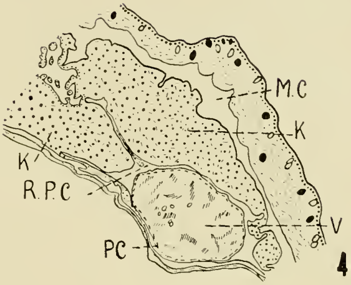

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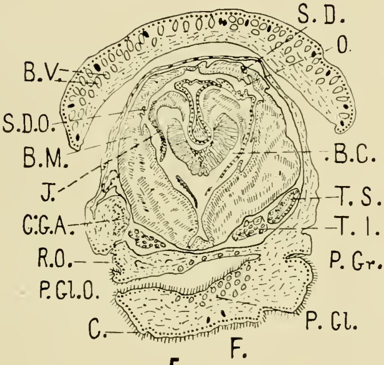

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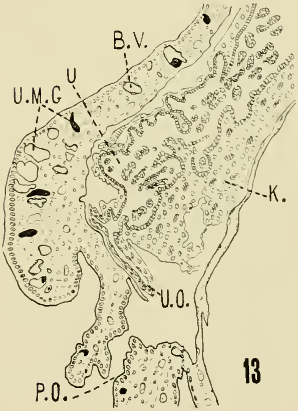

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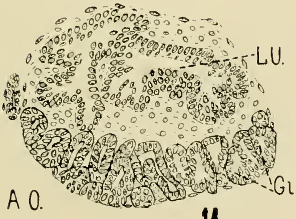

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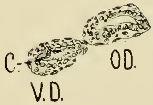

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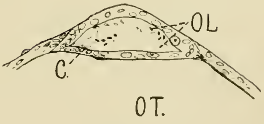

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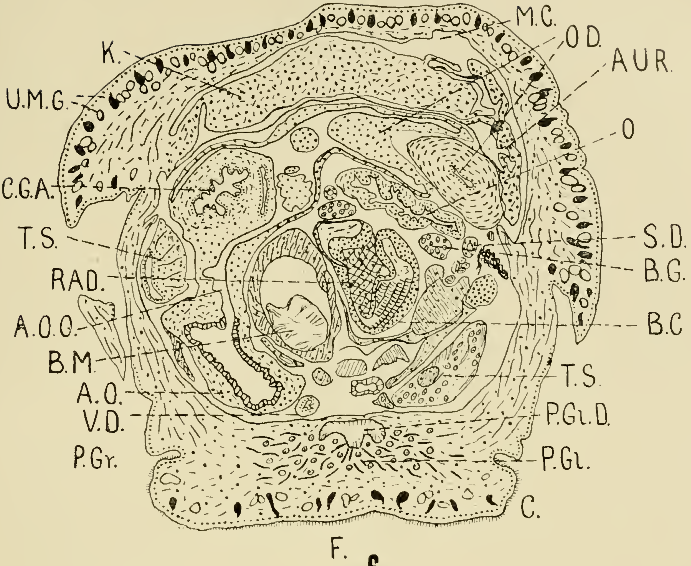
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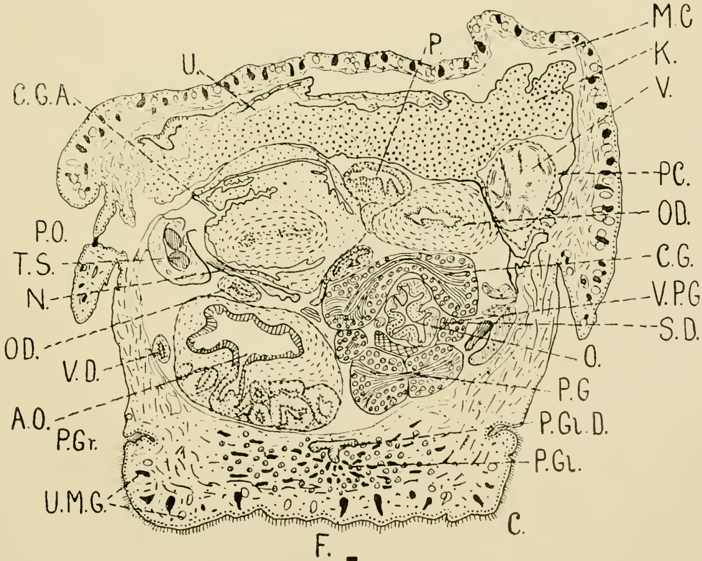
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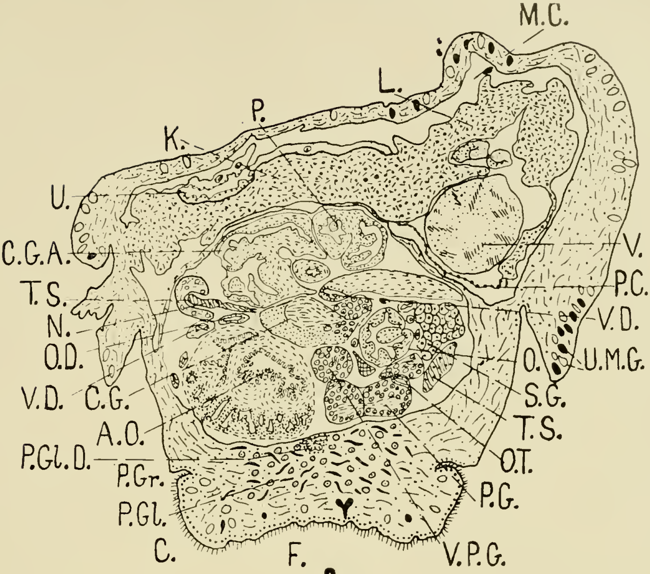
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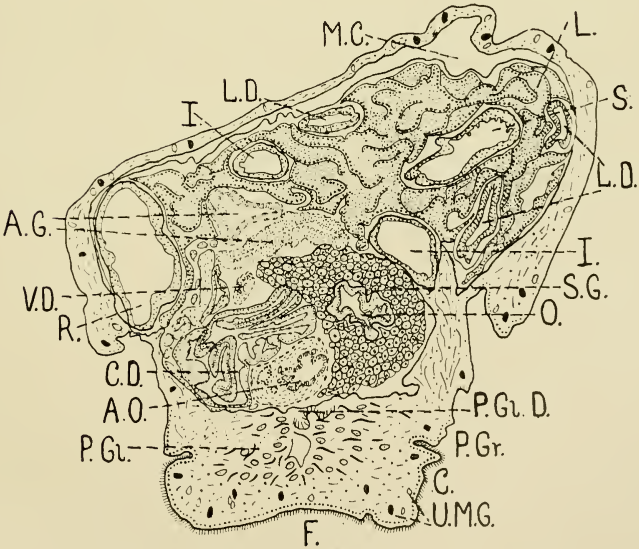
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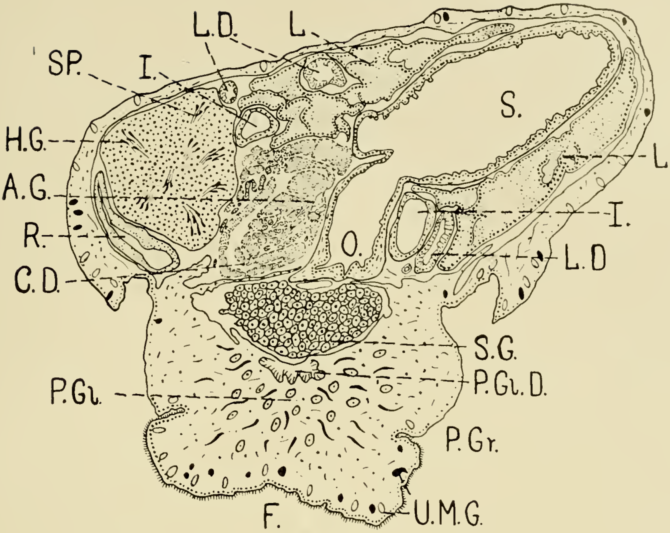
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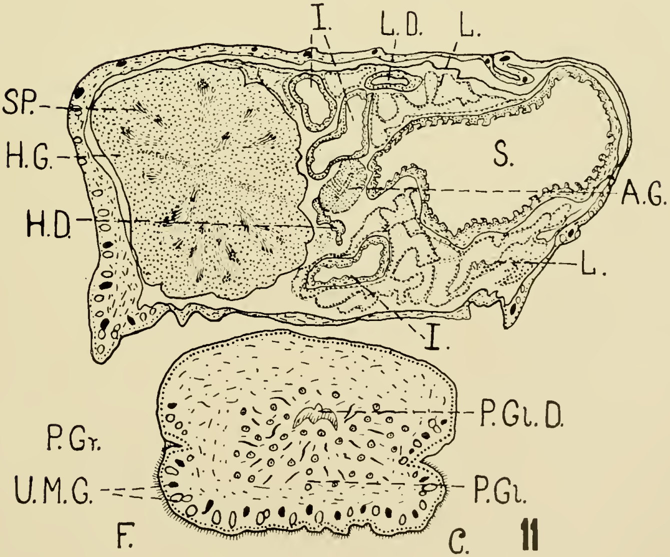
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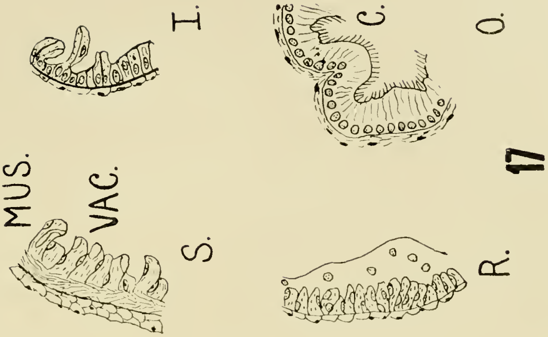

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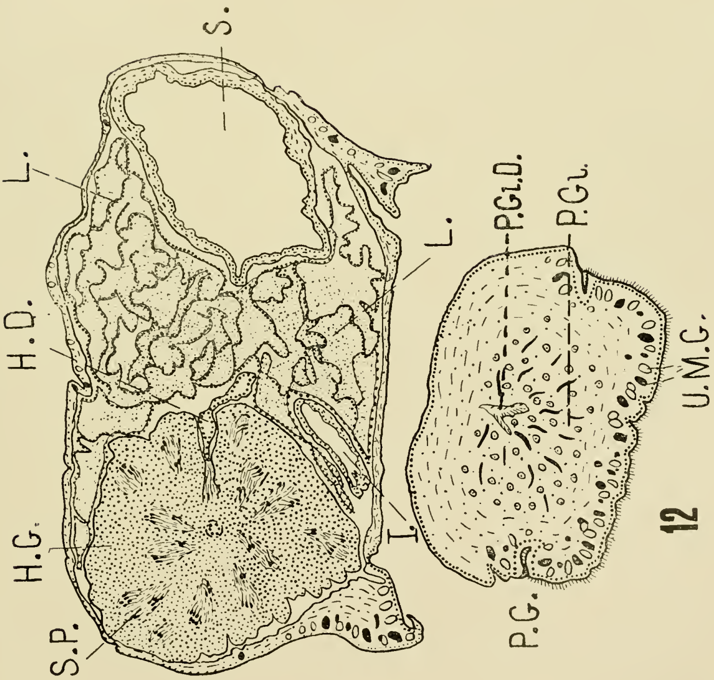

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[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXIV.—*Protozoa Parasitic in the Large Intestine of Australian Frogs.*

Part II.

By JANET W. RAFF, M.Sc.

(Government Research Bursar, Melbourne University.)

(With Plates LXX. and LXXI.).

[Read 14th December, 1911.].

In continuing my investigations into the Protozoa living in the large intestine of Australian frogs, I have obtained for examination, besides additional specimens of those frogs mentioned in Part I., the following:—*Hyla lesueurii* (several specimens); *Helioporus pictus*, *Pseudophryne bibronii*, *Crinia signifera* and *Crinia froggatti* (two specimens of each); *Pseudophryne semimarmorata* and *Hyperolia marmorata* (one specimen of each).

In these last seven species I have found nothing new with the exception of a new *Opalina* in *C. signifera* and a new *Amoeba* in *Hyla lesueurii.* I have also to describe two more new species of *Opalina* from *Limnodynastes dorsalis*, together with some abnormal forms from a frog of the same species. Most of the frogs contain the usual *Trichomonads*, *Nyctotherus cordiformis*, and one or more species of *Opalina.* The new *Amoeba* from *Hyla lesueurii* also occurred in *H. aurea* and *H. peronii*, as well as in tadpoles from various localities.

Opalina tenuis, n. sp.

This binucleated form was found in the large intestine of two specimens of the brown froglet, *Crinia signifera*, one coming from Narbethong, near Healesville, the other from Mentone, for both of which my thanks are due to Miss O. B. Davies. B.Sc. I have also found it in another small frog from Narbethong, which I take to be *Hyperolia marmorata.* They were present in very large numbers, and measured on an average 530μ long, and 36μ broad. They present a very attenuated or drawn-out appearance, and exhibit the usual corkscrew-like motion (Plate LXX., Fig. 1). The cilia are very long and of much the same length all over the body (Plate LXX., Fig. 2), but at the anterior end they are much more numerous and thickly arranged. The anterior nucleus is situated very near the front end of the body, while the posterior one lies in about the middle of its length, or slightly in the posterior half (Plate LXX., Fig. 1). In the younger and shorter forms the position of the anterior nucleus varies, the individual represented in Plate LXX., Fig. 2, having it situated further down the body than is usual in the larger forms. This individual measured 215μ in length. The smallest forms measured 100μ in length. *O. tenuis* occurred along with *O. intestinalis* in *Hyperolia marmorata*, but in *Crinia signifera* it was the only species of *Opalina* present.

Opalina dorsalis, n. sp.

The species of *Opalina* previously found in *Limnodynastes dorsalis* are *O. intestinalis* and *O. binucleata*, the latter being a new one that I described in Part I. In a frog of the same species just examined, however, I found neither of these present, but two different ones, both of which seem to be new. They are binucleated forms, and were present in great numbers along with *Nyctotherus cordiformis.* The larger of the two I propose to call *O. dorsalis* (Plate LXX , Fig. 3). It is elongate in form and has a very broad anterior end, is slightly flattened, and swims along on either side, giving an occasional roll over on to the other side as it progresses. This enables us to see a thin edge which indicates that the animal is not circular in cross section, but broadly oval. It is ciliated all over with very long cilia, and the two nuclei are always situated in the anterior half of the animal. The most distinguishing feature of the species is the greater width of the anterior end as compared with the posterior. It tapers gradually towards the hinder end and terminates in a point. The cilia extend right to the posterior end. The average length is between 358μ and 430μ, and at its widest portion it measures about 72μ. The one drawn in the figure shows the characteristic corkscrew-like folds that the animal presents when moving along. It also shows the slight turn of the "head" end that is noticed during locomotion.

The species at first sight resembles *O. intestinalis* slightly in outline and position of the nuclei, but it differs from it in that the anterior end is broader in proportion to the posterior, which tapers more and ends more sharply than in *O. intestinalis,* and in that the body is slightly flattened and so would not be circular in cross section.

Opalina acuta, n. sp.

This other new species from *Limnodynastes dorsalis* is much smaller than *O. dorsalis*, and tapers very much towards the posterior end, forming a long tail-like process (Plate LXX., Fig. 4). The average length is 257 μ, and the breadth at its widest portion of about 38μ. The anterior nucleus is situated about 57μ from the front end, and the posterior about 10μ further on, and generally slightly nearer the ventral surface. The cilia are well developed on the body portion, but gradually diminish in size and number on the posterior process, until for a length varying from 25μ to 50μ from the tip of the process there appear to be none. As the animal moves along, the anterior end is slightly raised, and the dorsal surface appears flattened or straight, while the ventral surface is curved. The characteristic feature that distinguishes this species from others is the very long, thin posterior portion.

Abnormal forms.

In a specimen of *Limnodynastes dorsalis* coming from Heathcote, Vic., I found numerous forms of *Opalinae* varying in shape and also in the number of nuclei present. Their outlines as drawn with the camera lucida are represented in Plate LXX., Fig. 5. They measured from 120 μ to over 240μ in length, and I think must be regarded as abnormal forms, in which the nuclei have divided irregularly without the body dividing. They possess nuclei from two to eight in number, which do not seem to be arranged in any definite order. Some of them may represent abnormal individuals of *O. binucleata*, as for instance (a), (b), (c), (d) and perhaps (f); but others seem to be intermediate forms which are not sufficiently defined to identify.

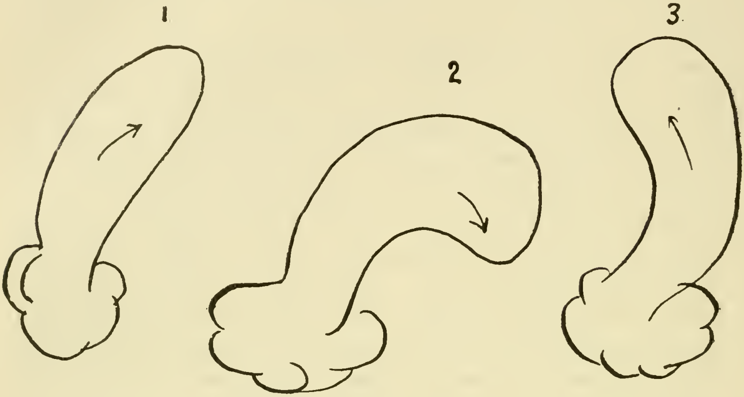
Entamoeba morula, n. sp.

This new species is found in great numbers along with *Nyctotherus*, *Opalinae*, *Trichomonads* and *Euglenoids*, in the large intestine of tadpoles of *Limnodynastes tasmaniensis* and others. I have not been able to ascertain in all cases the exact species of tadpole, but from the several localities from which they were obtained, as well as from their appearances, I should judge them to be, in addition to *L. tasmaniensis*, probably *L. dorsalis*, *Hyla aurea* and others. I have also found the animal on three different occasions, but in far smaller numbers, in the large intestine of frogs belonging to the species *H. aurea*, from Alexandra, Victoria; *H. lesueurii*, from Gippsland, Victoria; and *H. peronii*, from New South Wales. The following is a description of the amoeba as it appears directly it is taken from the large intestine and examined under the microscope. The amoeboid stage is roughly cylindrical and is distinguishable into a large elongated oval anterior portion, and a small posterior portion which is continually sending out rounded pseudopodia which are mulberry-like in appearance (Plate LXXI., Fig. 1). It is in these posterior pseudopodia, as well as in its habitat, that *E. morula* differs mainly from other allied forms. This new species is exceedingly active, and creeps along at a remarkable rate, only rarely remaining stationary. The average length is about 125μ, and the average breadth about one-third or one-quarter of its length, but as the shape changes quickly it is difficult to make accurate measurements. I measured one individual that was killed in osmic vapour and mounted in glycerine, that reached 166μ. The protoplasm is only rarely (see below) clearly differentiated into ectoplasm and endoplasm, the contents being as a rule scattered evenly throughout the body, excepting in the small posterior region, which is generally free from the larger granules. A very finely granulated appearance is generally seen in this portion, but at times it appears quite homogeneous and jelly-like. There is a single large nucleus which remains at the front end of the body during movement, but it is only faintly visible in the living animal (Plate LXXI., Fig 1). When stained in picro-carmine it shows up very clearly and is seen to be made up of a central dense granulated portion, a clear homogeneous peripheral portion, and a nuclear membrane closely investing the latter. It measures roughly 9μ in diameter. A contractile vacuole is sometimes visible (Plate LXXI., Fig. 6). In some instances individuals obtained from the tadpoles showed a very bright appearance owing to numerous green and brown bodies present in the protoplasmic stream. These inclusions appeared to be algal spores, diatoms, desmids or their cases, sand grains and other small pieces of débris. Although these were present in large numbers, the amoebae seemed to carry them along with great ease. Others again were found containing colourless oily contents only. Those found living in the frog never contained any green bodies, the protoplasm consisting mainly of ordinary small food vacuoles.

The protoplasm streams very rapidly and can be traced along the middle of the body to the anterior end and then back along the sides, but not extending into the posterior region.

When the amoeba is moving along, it always advances in a definite direction with the larger anterior end foremost. It assumes various shapes but retains as a whole a more or less elongated form (Plate LXXI., Figs. 1, 2, 3, 4 and 5). In creeping forwards a very slight bulging occurs at the front end, which appears to be made of ectoplasm only, being quite free from the larger granules. The protoplasm at once streams into this portion, and the whole individual is thus drawn forward. The contents stream so rapidly into the advancing portion that generally there is no actual pseudopodium (ectoplasmic) visible. The very front end of the amoeba appears to roll over gently and smoothly in a forward direction, and this seems to extend the animal slightly; with this action and with the protoplasm streaming ahead, the individual advances. Only occasionally have I observed the clear portion of the ectoplasm remaining at the front end where the protoplasm had not yet flowed into the projecting pseudopodium, and this is the only time at which ectosarc and endosarc are clearly separate. The direction of movement is changed by the bulging or rolling motion taking place to one side instead of at the front end, and the protoplasm streaming towards that direction (text figure 1).

Fig. 1.



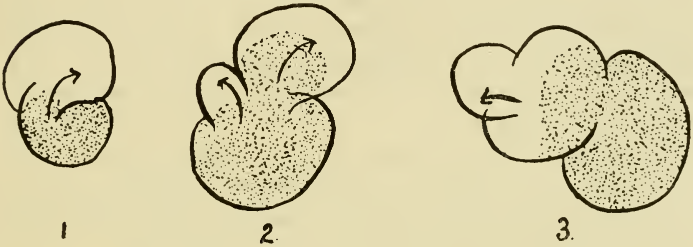
While the amoeba is thus advancing, a remarkable movement is going on in the posterior portion. It remains clear and jelly-like, but puts out continuously numerous rounded pseudopodia which merge into one another as soon as they are projected, and are renewed incessantly, giving rather a mulberry-like appearance (Plate LXXI., Figs. 1 and 2).

At times each individual pseudopodium is not visible, the whole forming a clear, oily-looking mass (Plate LXXI., Figs. 3 and 4).

Another peculiarity of this posterior region is that it appears to be able to act as a kind of sucker, anchoring the individual down to some support from which it can extend in any direction. I have also observed egestion take place at this region. The waste material is gradually discharged into it, and by the action of the pseudopodia is ultimately egested.

When the animal has been moving about for some time the differentiation into anterior and posterior portions disappears, and the amoeba becomes oval or spherical. This state of rest is generally assumed by them soon after they are removed from the intestine and put into saline solution, and one in this stage killed in osmic vapour and stained in picro-carmine is represented in Plate LXXI., Fig. 6. It measures about 60μ in diameter. The contractile vacuole is clearly visible. Occasionally I have observed an individual which has lost its usual form, but is still projecting pseudopodia. There is no indication of the differentiation into anterior and posterior parts left, the body being roughly rounded. The pseudopodia are round and large, and are thrust out rapidly, but there is no locomotion. The contents are propelled suddenly into these pseudopodia as they arise (text figure 2).

FIG. 2.



This may be an abnormality. Plate LXXI., Fig. 7, represents an individual killed in osmic vapour, showing two nuclei at the front end, one of which is slightly larger than the other. It is the only binucleated example I have come across.

In naming the animal I have placed it under the genus *Entamoeba*, which consists of species which are parasitic in the intestines of animals, in contrast to the genus *Amoeba*, which is considered to contain fresh water and marine forms only. Doflein (2) uses these two genera, and although Walker in 1908 (6) regarded the division as unwarranted, I prefer to follow Doflein's classification. In Walker's paper he says:—"Casagrandi and Barbagallo in 1897 proposed the generic name of *Entamoeba* for amoebae parasitic in the intestinal tracts of animals. This new genus *Entamoeba* has been accepted by Schaudinn (1903)." He goes on to say that it seems probable that the parasitic amoebae exhibit all degrees of parasitism from species restricted to one host, to species that can live either in various hosts or free, and because of this he thinks the genus *Entamoeba* does not appear to have any reason for existence.

Comparing *E. morula* with Grassi's species, *E. ranarum* which is parasitic in *Rana esculenta,* we see no resemblances at all, and *E. morula* is fully four times the size.

It resembles, however, the freshwater amoebae, such as *A. limax*, *A. villosa* and *A. pilosa* in being roughly distinguishable into anterior and posterior portions, and in having specially modified pseudopodia at the posterior end. These pseudopodia vary in the different species, and help to form the specific differences. These species are figured by Cash (1), and in his description of *A. limax* he notes that Penard points out a "peculiar habit of changing the direction of its march by a movement of the anterior portion of the body 'en masse' to the right or left, whilst the posterior portion remains stationary." This seems to show a resemblance to the peculiar way in which, as I have already noted, *E. morula* can be anchored down by the posterior portion.

The figures on Plates I. and II. of *A. villosa* given by Leidy (4) resemble very much the appearance of *E. morula* so far as the anterior end of the animal is concerned, during locomotion, but the posterior end is, of course, entirely different.

Additional note on Entamoeba morula.

Having completed this short paper, and still having a few more *Limnodynastes dorsalis* tadpoles, I examined again the intestinal contents of four or five individuals and found *Entamoeba morula* still present in large numbers, but a peculiar point was noticed for the first time—namely, the presence of a stiff process or flagellum-like organ situated at the anterior end (Plate LXXI., Fig 8). It seemed to project from the body at almost any angle, and was quite stiff and motionless. Only by the protoplasm of the front of the body moving or rolling over was the position of the flagellum altered. There generally seems to be a slight extension of the protoplasm forming a tiny conical projection which bears the flagellum. This is always situated close to the nucleus and, in some cases, seemed almost to be connected with it. The specimens which showed the flagellum best were those that were advancing very slowly. With close observation on those progressing rapidly, at first one would say there was no sign of a flagellum being present, but in three or four instances, after close watching, the animal moved into a certain position and the organ became visible. It may be that it is always present, but invisible owing to the fact that during more rapid forward movement of the protoplasm it becomes trailed underneath or above the anterior end of the body. The fineness of the process and the granular nature of the protoplasm prevented me from seeing it, excepting when it was lying or directed away from the body. I have been successful in killing and mounting only a few of these showing the flagellum, and on examining again the specimens mounted a few weeks ago, on which, along with the living animal, the first description was made, I can see no trace whatever of the organ. It may therefore be present at certain times only. In killing and mounting, however, as it is so very fine, it might easily be lost.

The individuals just examined possessing this flagellum had very few posterior pseudopodia, and sometimes none at all. The streaming was generally very rapid, and in some specimens there seemed to be a small portion at the extreme anterior end into which the protoplasm did not flow (Plate LXXI , Fig. 9). In this portion the nucleus was situated.

LITERATURE.

Same as in Part I., and in addition.

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EXPLANATION OF PLATES.

Plate LXX.

All figures drawn with camera lucida.

Fig. 1. Three specimens of *Opalina tenuis*, n.sp., showing general outline and position of nuclei.

Fig. 2. Young individual of same, showing cilia. (High power.)

Fig. 3. Drawing of *Opalina dorsalis*, n.sp., showing ciliation, outline and position of nuclei.

Fig. 4. Same of *Opalina acuta*, n.sp.

Fig. 5. Abnormal forms of *Opalina* from *Limnodynastes dorsalis*.

Plate LXXI.

A.P.	Anterior portion.
C.V.	Contractile vacuole.
N.	Nucleus.
P.P.	Posterior portion.
V.I.	Various inclusions.

Fig. 1. Diagram of *Entamoeba morula*, n.sp., drawn from the living animal, showing the characteristic posterior pseudopodia. The nucleus is only faintly visible.

Figs. 2, 3 and 4. Diagrams of same killed in osmic vapour and stained in picro-carmine.

Fig. 5. *E. morula*, after having been left in saline solution for some time, then killed and stained. Posterior pseudopodia disappearing.

Fig. 6. Same, having assumed a spherical shape.

Fig. 7. Individual with two nuclei.

Figs. 8 and 9. *E. morula* showing peculiar anterior flagellum-like organ.

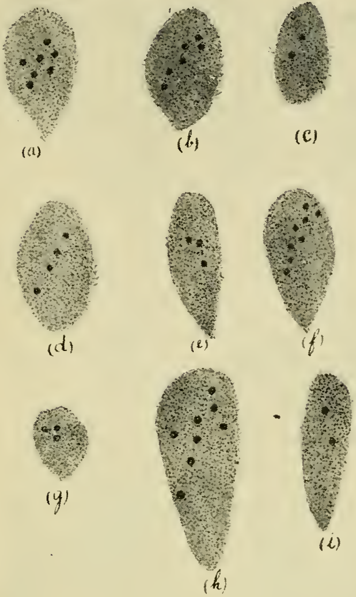


FIG 5

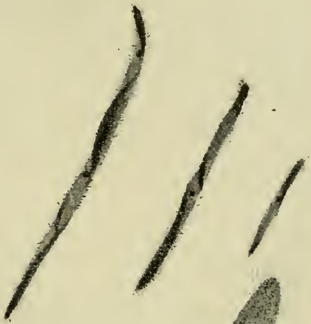
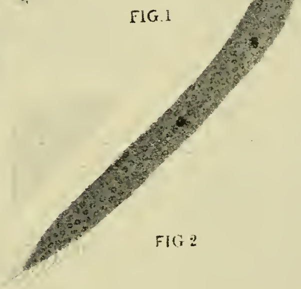


FIG. 1



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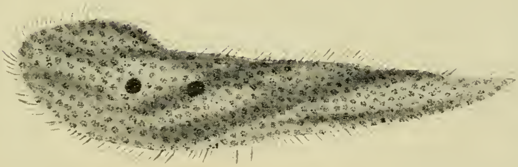

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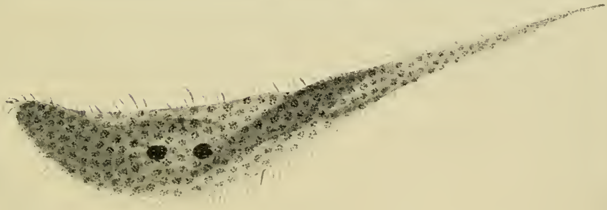

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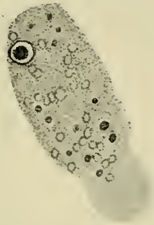


FIG.4

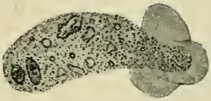


FIG.7

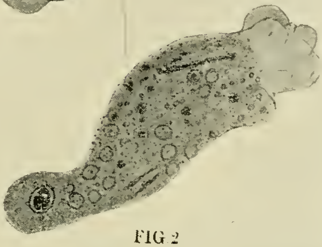


FIG.2

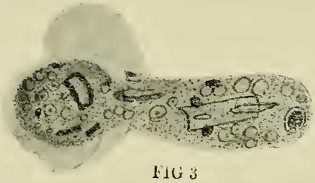
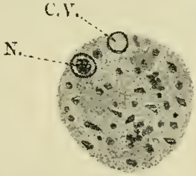


FIG.3



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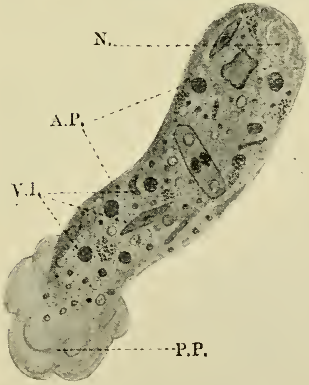
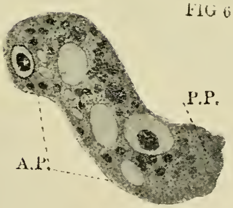


FIG 1



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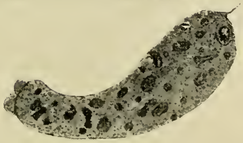

FIG.8

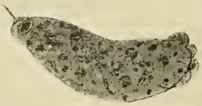

FIG 9

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXV.—*The Tropics and Pigment: The Physical Properties of Pigment, and its Physiological Importance in the Protection of Living Organisms, Especially Man.*

By WM. LOWE, M.B., B.S.

[Read 14th December, 1911.].

In 1906 I set out on a world's tour, which extended over a period of three years, and embraced in its itinerancy the eastern part of Australia as far as Port Darwin, Java, Malay States, Eastern China, and Mongolia, Japan, Canada and the United States, the Countries of Europe, Asia Minor, Egypt, Nubia and India.

I made the object of my travels the solution of the Race Question, which resolved itself into three divisions of enquiry, viz:—

1. The physiological importance of colour in man.
2. The relation of man to his environment.
3. The purpose of Race.

It is with the first of these questions that we are now concerned, which enquiry has been extended to include all living organisms.

Before proceeding to discuss the subject, it is advisable to give some account of the current literature upon it. The International Scientific Catalogues up to 1910 record many contributions upon pigmentation, but such as I can obtain in the Melbourne libraries deal chiefly with the anomalies of pigmentation or the questions of climatology, and with these may be included Keane, Scholes, and the Report of the last Race Congress held in London in 1911. The only work that need seriously demand our attention is Woodruff on "Tropical Light."

On page 85 he truthfully states:—

"Man is invariably covered with pigment which acts as an armour to exclude the more harmful short rays, and, moreover, the amount of pigment is in direct proportion to the intensity of the light of the country to which his ancestors had proved their adjustment by centuries or millenniums of survival in health and vigour."

But he misses the mark when he writes on page 68:—

"Of course the surest colour is black, for it destroys all the short rays, but as it transforms them into long rays the animal would be put in jeopardy from heat. . . . Hence black animals are almost always nocturnal."

Among these nocturnal animals Woodruff includes the black man:—

"The negro is really a nocturnal animal, like other black animals of the Tropics."

And further, when he discusses "Hirsuteness," his curious statements are almost grotesque, as shown in the following extract:—

"We rarely appreciate how transparent the scalp and skull really are. A candle in an empty skull shines through quite plainly. Hence a hairless head would permit strong light to penetrate to the delicate nerve cells which are here directly on the surface, and it would be fatal. The greater amount of light there is in a country, the thicker and blacker is the head hair. It is perfectly evident why the ancient European's wavy hair should become more and more kinky as man slowly migrated south, for it is thus a better protection from light. There is then no enigma in the apparently useless masses of kinky hair of the negro. The hair is not needed as protection from the heat or cold, for it is profuse in all countries, but it is a protection from the light."

Leaving Dr. Woodruff for the present, we are now free to seek for further evidence of the present state of knowledge on this question from the actions and utterances of the Melbourne academic authorities.

Professors Spencer and Gilruth, at the request of the Commonwealth Government, visited this year the Northern Territory, to survey the land in favour of a white settlement. They have now returned, and their report is favourable. Professor Osborne, in the course of the 1911 University Stewart Lectures on "Climatology" (as yet unpublished) prefaced his remarks by stating that he was on the eve of an ethnological tour, during which he hoped to come to some solution of these difficulties. He went on to declare himself in favour of race purity, and said that by the aid of red roads and a system of cool storage, with due regard to wet bulb readings and hygiene, the white man might ultimately hope to maintain a permanent hold in the tropics. Professor Allen, in a personal interview with the writer, also declared for race purity, and hoped that by the aid of science and the inculcation of habits conformable to the situation, the white man might maintain a permanent occupancy of the tropics. He instanced the present condition of the Panama under American administration. He, however, did not state that the great mass of unskilled labourers were coloured men gathered from anywhere and everywhere, while the skilled white labour had all the protection that American ingenuity could contrive for them.

Then again we have Dr. Barrett's letter in the "Argus" of October 14th, 1911, appealing for a Chair of Anthropology, in which he writes:—

"We might from such a Chair learn accurately how it is that the coloured man so far holds the Tropics. We might discover the elements of structure and functions which he may possess and we do not, that has enabled him so far to hold his tropical dominion."

And it is to this enquiry that the following statement is an answer, viz.:—

That the pigment of a black man protects him against the violence of radiant heat, as well as against light and actinic rays, by converting these energies into actual heat, which in turn is dissipated by the evaporation of moisture, this moisture being the result of the reflex stimulation of the sweat glands set up by the heated pigment, which is buried in cells in close contact with the nerve terminals.

This statement will explain the difference between heatstroke and sunstroke; why a Chinaman carries a fan, and an English tourist an umbrella. These questions are dealt with in another portion of the paper. But what is more important to Australians, it declares that tropics must ever remain the home of the coloured man.

Some evidence may now be adduced in support of the above statements. The truth will be obvious to those who are familiar with the laws which regulate radiant energies and the wet bulb thermometer as recorded in Balfour Stewart or Deschanel's Elementary Physics, combined with a knowledge of the histology of the skin as in Schäfer, and of the functioning of the sweat glands, to be found in any up-to-date work on physiology.

Physical science clearly demonstrates the fact that the pigment embedded in the rete malpighian layer of the skin of man and animals, will, in proportion to the density of the deposit, arrest the radiant energies of the sun, transforming and absorbing them as heat. This, in a measure, is advanced by Woodruff, but his difficulty was the disposal of the heat, for he only regarded pigment as a protection against the evils of light, but which would otherwise render the coloured man more vulnerable to heat. To get over his dilemma he describes the black man as a nocturnal animal. He failed to see that pigment is in a position to control the functioning of the sweat glands, and that instead of the heat being absorbed and dispersed by radiation, it could be dissipated in the evaporation of sweat. Woodruff, on page 86, states:—

" Undoubtedly the negro, when in the shade, is able to radiate heat better than whites, and this enables him to keep cool in the Tropics, but put him at a disadvantage in the North, where a white man can keep warmer with less clothing and less fire in the house. But it is a secondary cause enhancing the first, because, when it comes to a question of light and cold, Nature makes no mistake, but selects a colour able to exclude the light."

In the disposal of his body heat the pigment of a black man may give him some advantage, as an absorber and radiator, over the white man, but a black man is something more than a pigmented lump of clay, and even in the matter of loss of heat by evaporation of sweat, something more than a porous water bottle. He certainly responds to the laws that regulate the heating and cooling of inanimate things, but it is all important that we should recognise the physiological significance of the histological elements that lie buried in his skin, constructed to meet the exigencies of light and heat.

The pigmented epithelial cells which form the rete malpighii lie in contact with the corium. Through the meshes of the rete, filaments of the nerves pierce and interlace over its surface, so that the particles of pigment are in the closest contact with the surrounding nerve structure. Thus the variations of internal and external temperature which affect the pigment granules, would be directly imparted to the nerve terminals, and thence a communication to the central nervous system, with a corresponding reaction on the superficial blood-vessels. If the pigment is heated, a dilatation of the blood-vessels follows, with a flushing of the sweat glands. If the pigment is chilled, then a contraction of the blood-vessels takes place, which tends to prevent the loss of heat. It is natural, then, to conclude that pigment renders a man more sensitive to the cold, but this offers no impediment to a coloured man's progress, or even a black man's, for we find them both wandering from the equator to the poles, The Laplander and Eskimo are coloured men, and it was reported in the daily press that an American negro accompanied Captain Peary in his final rush for the Pole. Captain Peary's reason for this was that he considered that the black man, on account of his pigment, was better able to meet the emergencies that might arise from exposure.

Experimental evidence of the physical properties of pigment can be easily demonstrated by a piece of smoked window glass. We are all familiar with the protection that the deposit of smoke affords to the eyesight, but to appreciate the fact that it will also protect us from the sun's heat, alternately interpose between the exposed skin and the sun's rays a piece of glass smoked, and another not smoked. The effect can be heightened by concentrating the sun's rays with a biconvex glass condenser. The carbon will transform and absorb the rays in proportion to the density of the deposit. The heat will be radiated, but it may be dissipated by the evaporation of fluid if some spirituous liquid is poured over the glass. A similar result was obtained by the use of melanin pigment. The pigment for this experiment was procured by Dr. Stapley, of the Melbourne Veterinary School.

To show that pigment interferes with the passage of the sun's rays through animal tissues, the radiance of translumination of an electric lamp placed in the mouth will readily demonstrate this fact by comparing the fair with the dark skins, or by artificially darkening the skin with melanin pigment, burnt cork, sol. nitrate of silver, etc., or, perhaps what may be more simple, compare the transparency of variously pigmented skins by holding their hands before a beam of sunlight.

Our next object in the course of experimental evidence is to show what proof there is of heated pigment re-acting on the circulation, and increasing the activity of the sweat glands. From personal experience I know that heat reddens the skin and promotes sweating, and from personal observation I also know that the black man, of all men, is a profuse sweater.

We can, so far, sum up this discussion by confidently affirming:—

(1) That pigment, in proportion to the density of the deposit, renders the skin opaque to the sun's rays.

(2) That pigment transforms these energies into heat.

(3) That the temperature of the pigment reacts on the blood-vessels of the skin.

Thus, heated pigment induces sweating, whereby heat is dissipated.

Heatstroke.

From what has already been stated, it can be concluded that in the shade, all other things being equal, the power to resist high temperatures, dry or moist, is in favour of the pigmented skins, but the individual will succumb when it has reached the limits of his physiological activity. In exposure to the sun, there is an obvious advantage that pigmentation bestows on diurnal animals. It permits the loss of the body hair so that it shall not be an impediment to dispersion of heat by the evaporation of sweat, as with the buffaloes of Southern Asia. To man it gives the same security, his pigmented skin enables him to do without clothes, and nature, as is well known, reduces the hair of the scalp in many negroes to small, woolly tufts whereby danger from heat is reduced to its minimum.

It is a curious deduction of Dr. Woodruff to conclude that a negro's kinky hair is designed by nature to protect him from light, especially in face of the evidence he might have obtained from Southern Asia, where millions shave their heads as a political or religious observance, and freely expose themselves to a tropical sun without any fear of disaster. Such could not be tolerated did it in any way imperil their comfort, let alone their life. The coloured man wears a turban because he wears his hair.

Sunstroke.

Sunstroke menaces the white man, and he is apparently the only animal that can suffer from it. When you enter the tropics your first concern is to secure a helmet hat, for your acquaintances will have warned you of the dangers you run if you dare to expose your head and nape of neck to the sun. A few minutes is sufficient in some instances for the sun to exact its penalty. Thrust your hand into ice cold water for three minutes, and it will chill your whole body by means of the circulation. Expose your head or nape of the neck for three minutes to a tropical sun, and enough of its energies are poured into the brain to seriously affect its function. They pass into the cutaneous tissues, and are carried thence by the circulation to the nervous system, or, from analogy with the shadow of the Roentgen rays, direct rays from the sun may be transmitted through the scalp and skull to the brain direct.

I do not purpose discussing the pathology or any other of the factors that enter into the aetiology of sunstroke. It suffices to state, as already demonstrated, that a pigmented skin arrests the sun's rays, so that a black man in the normal circumstances of his life cannot suffer from sunstroke; but in the unprotected white man, these rays are free to enter with inevitable disaster.

The Chinaman and His Fan.

The Chinese present many gradations of pigmented skins, from a light lemon colour to a dark tan.

Canton city produces the finest samples of the lemon yellow, while the coolie and the peasant of the southern provinces possess the darkest tan. One of the most familiar sights to be seen in the streets of the European settlement is a lightly pigmented Chinaman with his head shorn and bare except his pigtail, clothed in his native garb, sauntering along flapping his fan, evidently for the sake of comfort rather than from any fear of his safety. He is sensitive to heat and not to light. Putting this into scientific phraseology, his skin, in relation to the demands of his environment, is diathermanic and non-actinic.

Diathermancy is not a term often used in experimental physiology, vegetable or animal, for I have only met the word once, and then in Ewart's translation of Pfeffer, where it is stated that the essential oil exuding from a plant interferes with the diathermancy of the atmosphere. Deschanel gives experimental evidence on this subject. Diathermancy is the quality of transparent bodies which permits the passage of radiant heat. This quality varies with the nature of the substance, also with its colour and its degree of opacity. This property of transparent bodies can easily be demonstrated in the sunlight with a few pieces of window glass, plain and coloured, a convex glass condenser, and some inflammable material, such as paper or matches.

Interpose these glasses between the condenser and the match, and note the time it takes to ignite them. Still better, use aniline dye, first with a transparent dye and then adding a mordant which causes a deposit on the glass, and makes it more or less opaque. It then resembles the condition of the pigment in the skin. This experiment distinctly shows that colour interferes with the passage of radiant heat; but with a deposit thrown down by the mordant, the heat can be entirely excluded.

The skin, which is more or less transparent in a white man, as shown in the act of blushing, permits the transmission of radiant heat as well as light; but the black man is born to blush unseen, for his pigment makes his skin opaque and prevents the passage of these rays.

The comparative value of pigment in obstructing the passage of the sun's rays has been already referred to in this paper by the experiment of introducing an electric light into the mouth and noting the illumination. In the white man the transparency is most marked, less in the yellow and least in the black man. So it is safe to assert of the Chinaman and his fan that his yellow skin will control actinic radiations, while it permits the passage of yellow light, and with it more or less radiant heat.

The English Tourist and His Umbrella.

Any of us who have lain suffocating on the deck of a steamer as it passed through the Suez Canal and have seen the native Arab children racing along the banks begging for "backsheesh" must be compelled to admit that the Arab has acquired some immunity which the white man does not possess. The traveller on the steamer enjoys the advantage of hygienic surroundings, and is protected by all that science can afford him, except a refrigerator, yet the Arab runs across the burning sand, into which he frequently tumbles, with a happy unconsciousness of any discomfort, and sublimely ignorant of the perils of light, heat, and a humid atmosphere. This incident accurately illustrates the relative position of the white and black races in the tropics. Visitors only invade them during the winter months, and then they are armed with every comfort. At the approach of summer the white races fly to the hills or some other clime for safety. The only explanation to the situation is that the white man is both actinic and diathermanic, and feels the necessity of protection, even to the use of an umbrella.

The use of the words actinic and diathermanic mean that the white man's tissues permit the penetration of light and heat rays. How far these rays penetrate it is difficult to determine. Translumination, as already shown, gives evidence of transparency. The light rays are visible, and the presence of actinic energy is revealed by photography. To determine the passage of radiant heat the following experiment may be performed:—Place in the mouth, with the electric lamp, a thermometer, and with the face of the individual near a thermopile, all other sources of heat being eliminated, discover, if possible, the presence of radiant heat. But of the actual resistance of the tissues to sunlight the following simple experiments will give some evidence. Free blood is opaque. Smear a little between two glass slides, then hold it to the sunlight, and it will be seen that the blood obstructs vision, though transmitting a diffuse red glare; now interpose the test slide between a condenser, focussing sunlight on the head of a match. It will not ignite, the blood having absorbed the heat rays. While recognising the abnormal condition of the blood in this experiment, we can with some assurance conclude that blood in the tissues will have power to reduce actinic and heat energy to actual heat, and absorb all light rays but red. Thus the reddening of the skin on exposure to heat is really nature coming to the rescue. It not only flushes the sweat glands, but its flowing streams gather up the heat and carry it to other parts of the body to be dissipated.

The Tropics must ever remain the home of the Coloured Man.

The white man, in his natural home, lives under the happiest circumstances for the condition of physical adornment. He inherits all the charm of variety, while his less favoured coloured brethren are burdened with the brand of monotony, and suffer by comparison. But let the pale face wander, then, the fairer his skin, the more susceptible is it to the ills that such flesh is heir to. The white man is truly the product of green fields. Born in areas where the hours of sunshine are duly recorded, he lives a strenuous life; but when he leaves his native land his capacity for labour varies inversely as he nears the equator or the poles.

On reflection the above statements should now be obvious, but it may be of advantage to adduce some further evidence in their support. The Panama is a noble tribute to medical skill; there the death rate of the white population has been reduced to half that which it is in New York; yet the 6000 whites in the Panama are the black man's burden, as they are everywhere else in the tropics. Cornish's "History of the Panama" and Weir's "Conquest of the Isthmus," both published in 1909, give interesting and instructive accounts of the situation. The great army of the toilers in the Panama are coloured men, gathered from anywhere, amongst whom these writers include Italians and Spaniards.

Since prehistoric times the northern white races have been over-running the south of Europe, but Southern Europe still remains coloured, the great mass of its inhabitants being as dark as many of the Asiatics of Southern Asia. Apart from the question of disease, my own experience of the tropics has shown me that the white man in the black man's country degenerates mentally, physically, and morally, and that his children are attenuated specimens of his race. Thus I am compelled to affirm that labourers will ever need the protection of colour in direct relation to their environment.

The Complex Nature of Animal Pigments.

As our subject was extended to include all living organisms, some reference must be made to the complex nature of their pigmentation. To understand the reason of the diversity of colour that appears in animals, it is necessary to look into the conditions that give rise to the need of colour, and they may be best presented by the following homely illustration:—

A man may put on any old coat to protect himself from the sun's rays, but a soldier needs the security of colour, and wears khaki. To distinguish the officer, he is adorned with gold braid and buttons, a most powerful weapon in the struggle for sexual selection. So it is with animals. Any old coat seems to serve our domestic companions, whilst animals that live in peril of their lives are warily clothed; and others, who are free from that anxiety, are adorned for the struggle of sexual selection.

Behind these *post hoc* performances there is some subtle agent at work, the biological factor, life. A man's circumstances may demand a coat, but these circumstances do not make the coat, and so it is with Nature's "visible garments." But the coat is constructed out of matter and force, and so one must conclude that the factors that are concerned in the production of pigment are—life, matter and force. In declaring an adherence to this three-fold division, one is privileged in that much of the dogma that has been founded on hypothetical science is in a state of flux. But life, matter and force exist, and in distinguishing the vital from the physical I will here simply assert my claim as an article of faith.

The influence of breeding on colour determines the importance of the biological factor, which shows its highest effort in sexual selection. It is not required to give evidence that matter, as a change of food, and force, as a change of environment, will also effect a change in the colouring of various animals, but what is remarkable is the subtle adaptations of Nature to the refined variations of environment. This is seen in the tapeta that exist in quadrupedal mammals, whose eyes are in a position to receive a great amount of reflected and transmitted rays. The tapeta, which are, no doubt, needed for the protection and function of vision, are so varied in their colour schemes that they almost rival in beauty anything that Nature has attempted for the purpose of sexual selection. This fact will account for the varied colour schemes that appear in the coats of animals living continuously in subdued and modified sunlight, and which are so essential for their protection.

Chlorophyll and Plant Life.

The object of including vegetable organisms in this discussion is to show that there is a common purpose underlying the functions of pigment in all living organisms. Vegetable pigment is much more complex than that of the surface pigment of animals, yet it is also designed to protect the tissues from the violence of the sun's energy.

The sun's energies are necessary for physiological processes that take place in vegetable organisms, but while they are the constant stimulant of these vital phenomena, over-stimulation can suppress the activity of these processes and bring about the ultimate destruction of the living media through which they are being transmitted. Therefore, plant life is compelled to construct a wall of resistance by which these energies can be regulated. It is evident that this purpose is mainly accomplished by the deposition of chlorophyll. Chlorophyll, because of its colour, has the power of controlling light rays, and also because of its colour and opacity, of obstructing the passage of heat rays, and it therefore regulates the diathermancy of the tissue involved. Its capacity in these directions will vary with the density of the deposit of pigment.

The truth of the above statements can be demonstrated, as was done in the case of animal pigments, with aniline dyes, chlorophyll pigment, or the translumination of vegetable tissues.

The synthetic properties of chlorophyll depend chiefly upon its chemical constituents, and no doubt the physical properties of the pigment may enter largely into effecting the changes that take place in the chloroplasts. But we are not concerned with either the chemical or vital processes themselves, we are only dealing with the physical properties of chlorophyll as a pigment, and are more particularly concerned in showing that it has the power of controlling the activities of light and heat rays; and this will be readily conceded if we attempt to explain the ordinary phenomena that occur in the course of plant life.

Young plant life is vigorous, and radiant energies are freely demanded for the purposes of rapid growth. Here it will be observed that the deposition of pigment is least. As the season and growth advance the deposit increases, which in turn must lessen the chemical activity of light, and at the same time reduce the diathermancy of the tissues. This means the conversion of more of these radiant energies into actual heat, till at the end of the season or of growth the chlorophyll has become so dense that it will, for the greater part, if not wholly, transform these energies into heat. With annual plants, as in grain crops, the pigment changes its colour to a yellow pigment, xanthophyll. This pigment has the power of further reducing actinic energy to heat, and at the same time, in some measure restoring the transparency of the tissue and allowing the transmission of radiant heat, which in due course completes the ripening of the grain. With the deposition of pigment, the growth of perennial foliage is completely arrested, as with the ivy, but by this means these leaves are able to secure the necessary heat that sustains them through the winter months, while in the summer desiccation is avoided by the transpiration of fluids.

Here again experimental evidence can be given in support by the translumination of the various coloured vegetable membranes.

It is not necessary to give evidence that Nature protects plant life according to the needs determined by its environment, nor is it required to prove the fact that British trees, like British people, find the struggle of life increases adversely as they near the equator or the poles.

We can, again, sum up the discussion by affirming of vegetable pigments:—

(1) That the pigment, in proportion to the density of its deposit, renders the tissues opaque to the sun's rays.

(2) That pigment transforms these energies into heat.

(3) That the temperature of the pigment reacts on the circulation of the sap.

Thus heated pigment induces the transpiration of fluids whereby heat is dissipated.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt II., 1911.]

Art. XXVI.—*On Bitter Pit and the Sensitivity of Apples to Poisons.*

By ALFRED J. EWART, D.Sc, Ph.D., F.L.S.

(Professor of Botany and Plant Physiology in the
University of Melbourne).

[Read 14th December, 1911.]

Introduction (page 367).
Part I.—The sensitivity of apples to poisons (page 368); the influence of the cuticle and bloom of apples on the absorption of poison (371); apples more sensitive than other organisms (374); do apples accumulate and permanently retain mercury from dilute solutions? (375); the actual sensitivity of the pulp cells of apples to poison (377); the influence of age (382); bases generally present in soil (384); the action of poisonous plant products (387); alkaloids (388); acids (390); the specific resistance to poisons (392); the influence of ionization and of the respective ions (394); the nature of toxicity (399); the action of gases and volative substances (400).
Part II.—The problem of bitter pit (page 404); can surface poisoning produce deep seated bitter pit tissue? (409); the starch grains of bitter pit (410); the non-solution of the starch grains (411); the source of the poisons causing bitter pit (415).
Summary (page 417).

Introduction.

In the early part of the present year, Dr. White put forward as a tentative theory the suggestion that the defect known as bitter pit in apples might be associated with the use of poisonous spraying materials for codlin moth and other pests. She was able to detect lead in the bitter pit tissue of apples from orchards which had been heavily sprayed with arsenate of lead, and from her study of the ferments of normal and affected apples, was also led to the conclusion that the defect could only be ascribed to the action of a poison. She also pointed out that bitter pit appeared to be especially common on well-tended and well-sprayed orchards, and was much less so on neglected orchards, and showed that appearances resembling bitter pit could be produced by various poisons. Curiously enough this theory, although the first one based upon any experimental evidence as distinguished from observational and imaginative evidence, met with strong disapproval, and has popularly been supposed to be entirely discredited. In the present paper I hope to be able to bring forward conclusive proof of the poisoning theory of bitter pit, and also to show that it is not necessary to withdraw or modify any part of Dr. White's paper, except in so far as her tentative theory, that the source of poisoning might be from poisonous sprays, only holds good partly, for bitter pit may also occur in orchards which have never been sprayed with poisonous compounds, although so far as the evidence goes, it appears to be much less common in such cases.

Obviously the first point of attack was to determine accurately the specific resistance of apples to different poisons. Extraordinary variations are shown in this respect by different plants. Thus among the lower organisms we have *Spirogyra* which is sensitive to concentrations of copper sulphate down to 1 part in 100 million of water, and the green mould, *Penicillium*, which can grow and thrive on fifteen to twenty per cent. solutions of the same poison. O. Richter (Die Ernährung der Algen) has shown that coins placed in mere contact with diatom cultures on agar, exercise a marked deleterious influence upon the growth of these organisms, although the coins do not lose appreciably in weight. Between these extremes intermediate grades are known, according to the specific resistance of the particular plant protoplasm, and whether it has or has not the power of preventing the penetration of the poison into its living substance.

PART I.

THE SENSITIVITY OF APPLES TO POISONS.

The majority of the apples used for these experiments were special ones, mainly selected ones grown in an orchard rented by me, unsprayed, and kept in the cool stores for one to five months until needed. They included the following varieties:— Jonathans, Yates' Pippin, Rokewood, Rome Beauty, Scarlet Nonpareil and Five Crown. Owing to the exhaustion of the supply before the experiments were completed, a small number of purchased apples were also used, mainly of Five Crown. These were carefully cleaned and wiped in all cases to remove any poison that might be adhering to the skin. The purest obtainable salts were used, and supplies of specially pure distilled water were obtained from the Chemical and Physiological Schools. The Minister for Customs (Mr. Tudor) kindly consented to have chemical analyses made by the Federal Analyst (Mr. P. Wilkinson), of the apples used in order to determine the amount of poison necessary to produce artificial bitter pit, and various other points connected with this question. Mr. Wilkinson's aid has been extremely valuable, and has been most zealously and ungrudgingly given.

The first tests were made with sound, uninjured apples by immersing them in solutions of mercuric chloride, copper sulphate and lead nitrate of varying strengths. In all concentrations of less than 1 in 1000, a litre of solution was used to each apple.

Copper Sulphate.—Jonathans in solution for one week, and air one week.

One gram per 200 c.c. Large and small pits from 1 cm. to a mm. diameter, and extending about half their diameter into the pulp. On submitting the material to the Federal Analyst he reported "No copper detected." In all cases the apples were well washed in running water to remove any poison adhering to the surface before forwarding them for analysis.

One per 1000. Pits smaller and less numerous.

One per 5000. None of pits exceeding 3 mm. diameter, and 1-2 mm. depth.

One per 25,000. Minute superficial spots none exceeding 1 mm. depth.

One per 100,000. No perceptible effect.

Apples in distilled water one week, and in air one week. Lenticels slightly more prominent in some cases, no other effect.

Lead Nitrate.—Jonathans.

In 1 gram per 100 cc. 1 day. After 2 weeks in air, small well-defined pits 2-4 mm. diameter, and 1 to 3 mm. deep. The Federal Analyst reported "No lead detected."

After immersal in solutions of 1 per 1000, 1 per 5000 and 1 per 10,000 for one week, the apples showed in five weeks a few small spots on the surface not exceeding 1 mm. diameter and less than a millimetre depth, but no distinct pits.

With solutions of 1 gram in 25,000 and in 1,000,000 c.c. of water, no spots or pits at all appeared, even after one week's immersal, and subsequent keeping in air for six weeks.

In order to determine whether penetration was favoured by changes of temperature such as occur under natural conditions, apples were heated to 40 deg. C, daily for a week, and allowed to cool under a solution of 1 gram per 1000 c.c. Much air escaped from the lenticels (breathing pores), but only a few small pits developed under some of these, the largest not exceeding 3 mm. diameter after three weeks in air. If the temperature rises above 40 deg. C, the surface layer is apt to be scalded, but evidently changes of temperature do favour the entry of poison, but not as much as might be expected, and only through the lenticels.

Mercuric Chloride.—Jonathans.

In one gram per 100 cc. for one day, after one week in air, 28 large and small pits present, in 7 grams per 1000 after the same times, 29 mostly smaller pits developed. After immersal in 4 per 1000 solution for two days and one week in air, 13 small pits formed, and after the same times with 2 per 1000, three very small pits. After one week in 1 per 5000 and two weeks in air, several spots and seven small pits, the largest 3 mm. diameter appeared. The whole of these apples (5 experiments) were separately tested by the Federal Analyst, who reported that " the whole of the pitted portions in each apple (the peel was removed previously by a knife) was used for the test, no indication of the presence of a mercury compound was detected in any instance, and the method of analysis used was sufficiently delicate to detect the 1-100,000th part of one grain of mercury."

These results seem to show (1) that the sound skin of the apple is very impermeable to soluble poisons, (2) that penetration is possible through the breathing pores producing pits confined to the point of entry, and (3) the amount of poison so penetrating is extremely small. They also show that the fact that the State Analyst was unable to detect any lead or arsenic in the limited quantity of bitter pit apples collected by the

State Committee from unsprayed orchards did not dispose of the poisoning theory of bitter pit, as was naturally supposed to be the case by those unaware of the facts known by the plant physiologist in regard to oligodynamic poisoning.

The influence of the cuticle and bloom of apples on the absorption of poison.

Sound, unhandled Five Crown apples with a perfect bloom were (a) wiped with a rough cloth on one side to remove the bloom, and (b) had an equatorial band of bloom scraped off with a razor without injuring the skin, and were floated for 1 week in a solution of 2.5 grams of copper sulphate ($CuSO_4 . 5H_2O$) in 1000 c.c. of water. Examined a week later (a) showed scattered spots and small pits, 1 mm. diameter and depth on the wiped side, and a few minute spots on the unwiped side, whereas (b) showed a faint brown line joining an equatorial row of pits, varying from 1 to 5 mm. diameter, and from superficial to 4 mm. depth. Close examination showed, however, that the largest pits were under breathing pores, whose orifices had been enlarged by the scraping.

A similar test was performed with a solution of 1 gram of mercuric chloride in 1000 c.c. of water. The wiped side was browned and irregularly pitted, while the unwiped side was very faintly browned, but the surface remained smooth and round with several minute spots, but no pits.

To obtain additional evidence of the influence of the bloom, 15 Jonathan apples with a perfect bloom were selected, and without handling them the calyx and stalk were closed with melted paraffin. They were completely immersed in a 1 per cent. solution of mercuric chloride for one day, and then well washed. In one week they were covered with large and small bitter pits mainly confined to the breathing pores, but the general pulp remained sound, and the surface was barely or not at all discoloured, apart from the pits. They were then forwarded for analysis. The Federal Analyst reported, "The diseased pulp and skins were separately analysed. I did not succeed in detecting the presence of mercury. The procedure followed, from comparative trials with known quantities, would enable the presence of approximately 1-10,000th of a grain of mercury to be detected."

The waxy bloom was removed from a further set of 15 Jonathans which were immersed for a week in a half per cent. solution of mercuric chloride, allowing them to float and aerate themselves for one hour daily. The apples all had sound, unbroken skins, large stalks and well-closed calyces. They were covered with large dead brown patches, extending in some cases nearly to the core, and there was evidently a slight penetration at the calyx end, and still more at the stalk end of the fruit. Hence after thorough washing, a one centimetre cylinder of the core was removed, and the remainder forwarded for analysis.

The report from the Federal Analyst was as follows:—" The fifteen samples of apples referred to in the attached letter from Professor Ewart have been examined as to the presence of mercury compounds as detailed hereunder:—

A.	Mercury on the exterior surface of the apples (as removed by chlorine and washing) calculated as mercuric chloride	17 mg.
B.	Mercury contained in thin peelings, calculated as mercuric chloride	20 ,,
C.	Mercury contained in brown pit pulp, outer layers, calc. as mercuric chloride	16 ,,
D.	Mercury contained in deeper layers of pit pulp, calc. as mercuric chloride	18 ,,

" The quantities of mercury reported are probably, owing to imperfections in method of determination, slightly below the amounts actually present in the apples."

In this experiment the total volume of the solution was 2000 c.c. and of the apples 2760 c.c. The weight of mercuric chloride in the solution was 10 grams, and the weight of mercury found in the apples 71 milligrams, representing 96 milligrams actually absorbed of the chloride, or rather more than this allowing for losses in analysis. Hence the concentration in the apples after a week's immersal did not exceed 1-100th of that of the solution outside.

An exactly similar experiment was performed with 12 wiped Jonathan apples, but the calyx and stalk were covered with paraffin, and the time of immersal shortened to three and a-half days. The whole surface was affected, and more or less pitted and wrinkled. In one week the whole superficial pulp was browned in spots to a depth of 1 to over 10 cms. The Federal Analyst reported that "the quantity of mercury compounds recovered from the peel of the twelve apples was 0.036 gramme (as metallic mercury) and from the brown-coloured spots of the pulp 0.009 gramme. The amount of mercury recovered is considered to be less than that actually present." This is because of the relatively large bulk of organic material, which might in extreme cases cause reductions in the apparent amounts present, up to as much as 20 or even 25 per cent. Even then the total amount of mercuric chloride entering the apples would not exceed 0.06 gram, and that in the pulp 0.012 gram. This was spread over not more than one-third of the 1890 c.c. bulk of apples. Hence the concentration in the dead pulp after three and a-half days could not have been more than 1 in 5000, or 1-25th of that in the liquid outside.

A third experiment similar to the preceding one was performed with four wiped Jonathans, immersing them for three days in a 1 per 1000 solution of mercuric chloride. After well washing and keeping in air for 14 days, the whole surface was brown, discoloured and irregularly pitted, with brown pulp from 2 to 20 millimetres deep in parts. From these apples the Federal Analyst recovered 0.004 gramme as metallic mercury from the peel and pulp together. The apples had an original volume of 615 cc. The two litres of solution used contained 2000 milligrams, of which only four were absorbed by the apples. Here, as in the previous experiment, the concentration within the apple was very considerably less than that outside, and the concentration of poison in the deeper layers of dead pulp must have been extremly small.

Additional evidence of the influence of a waxy bloom in preventing the entry of poison was obtained by painting apples over rapidly with a very thin coat of low melting point paraffin. At a casual glance these apples showed nothing abnormal in appearance. Close examination was necessary to detect the treatment they had undergone. They were floated on half per cent. solutions of mercuric chloride, copper sulphate and lead nitrate for one week, and the artificial bloom then removed by wiping with a cloth and warm water. There were no signs of asphyxiation in this time, in spite of the blocking of the pores by paraffin, but the apples developed a slight alcoholic smell. After three weeks in air, all the apples remained quite sound, with no signs of any development of bitter pits superficial or deep-seated.

Apples more sensitive than other organisms.

All the poisoned apples from these and the following experiments[1], which were not used for analysis or microscopic examination, were fed to guinea pigs, and these included apples soaked in half per cent. solutions of mercuric chloride and copper sulphate, and then kept until a large part of the pulp was dead and brown. The guinea pigs, beyond occasionally showing thirst and micturating freely, showed no signs of poisoning, but they usually refused to eat the skin and worst rotted parts of the most strongly poisoned apples. In any case, in the course of several months each guinea pig ate at least twice its own bulk of poisoned apple pulp without suffering appreciably.

In addition, wiped apples were soaked in 0.5, 0.2 and 0.1 per cent. solutions of mercuric chloride, and in 1 and 5 per cent. solutions of copper sulphate for one week, and then kept until the surface pulp was rotted wholly or in part. The skin was then broken in places and infected with the spores of the green mould, *Penicillium*. The hyphae developed in the dead pulp nearly as rapidly as in dead unpoisoned apples killed by boiling, and more rapidly than in the pulp of sound apples. Spores were also formed freely, mainly from the broken surface of the skin. From the analyses given above, the percentage of mercury in the dead pulp cells could not have greatly exceeded 1 in 10,000, and since *Penicillium* can develop well on solutions containing as much as 15 per cent. of copper sulphate, it is not surprising that it should be more resistant to mercury than the pulp cells of the apple. Possibly its hyphae may be more or less impermeable to soluble mercury salts just as they are to copper salts, for since mercury is a general protoplasmic poison, once it enters living protoplasm in a soluble form it cannot fail to exercise a poisonous action.

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[1] Excepting those treated with alkaloids.

Do Apples accumulate and permanently retain Mercury from dilute solutions?

To determine this, six peeled quartered Jonathans, having a total volume of 820 c.c., were immersed in 6 litres of a 1 per 10,000 solution of mercuric chloride for one week until browned right through. The fact that the browning took place in the presence of mercuric chloride seems to show that it is not the result of the action of an oxidase ferment, but is the result of direct oxidation upon substances which either come into contact when the cell is killed or are protected from oxidation while it is alive.

The Federal Analyst reported that "the sample submitted for analysis has been found to contain approximately 50 milligrams of mercury compounds, calculated as metallic mercury. For the total bulk this represents 204 milligrams of mercuric chloride not removed by washing, but held in more or less permanent combination."

The residual solution, after the apples had been removed, was too dilute to test for mercury by volumetric means. It turned slightly brown with sulphuretted hydrogen, but formed no precipitate; it gave no opalescence with ammonia, and there was no perceptible change of colour when an excess was added to a 1000th normal solution of potassium iodide. Hence, to determine the amount of mercury present, a clean strip of pure copper was immersed in 1000 c.c. of the liquid. It took three weeks before all the mercury was deposited. The copper strips were weighed before and after heating in an atmosphere of hydrogen, the decrease in weight giving the amount of mercury deposited. One litre contained 38 milligrams of mercury, or 47 of mercuric chloride. Hence the apples had apparently absorbed approximately one half of the total quantity of poison; that is, 318 milligrams or 388 milligrams per litre; that is, three to four times the original concentration in the liquid outside. Hence the pulp cells of apples are able to accumulate such metallic poisons as mercury in greater concentration than in a dilute solution presented to them.

Additional evidence was obtained in the following way:—Two cubic centimetres of the pulp of two of the above apples were removed, and, after washing, placed in one litre of distilled water with a prepared Rome Beauty floating on top. The liquid was gently stirred daily, and after one week the apple was removed. The prepared spots already showed signs of poisoning, and after one week in air developed from a superficial browning to pits 1 millimetre deep. The 2 centimetres of poisoned pulp were then crushed, and kept in contact with a clean strip of pure copper for one week. No trace of mercury was deposited. The pulp was then treated with sulphuric acid, nearly neutralised, and kept in contact with a clean strip of copper for one week. A slight but distinct stain of mercury was formed, volatilising on heating, but not in sufficient quantity to be accurately weighable. Judging from a comparative test the total amount was a very small fraction of a milligram.

It follows therefore that the pulp cells do fix mercury, and that the mercury is liberated again by treatment with sulphuric acid. The poison that diffused from the dead pulp would at first be merely mercuric chloride in solution. Since the concentration outside was 388 milligrams per litre, not more than 0.7 of a milligram of mercuric chloride could have been present in solution in the poisoned pulp. This would produce at the most a concentration of 7 in 10,000,000 in the litre of water in which the prepared apple lay, and probably considerably less, since the poison as it exudes is being absorbed by the second apple. The special interest of this observation lies in the fact that if its rationale were not known, it might have led to the conclusion that the dead pulp of one apple was able to communicate a disease to the second one. Instances of oligodynamic poisoning may be much commoner than is generally supposed, and it is in fact possible that certain other diseases of plants and even animals may directly or indirectly have a similar origin. All that is necessary is to have sensitive cells capable of absorbing or accumulating very minute traces of poison. If these cells were in a growing tissue the symptom of poisoning might be an increased or abnormal growth, and if this kept pace with the accumulation of poison the latter might remain in an almost infinitesimal concentration, and yet produce a pronounced external or internal effect. This is, of course, a suggestion only, but one that seems worthy of consideration, particularly in regard to certain abnormal or cancerous growths, not due to specific disease organisms.

Hypodermic injections of poison.

In order to determine the actual sensitivity of the pulp cells to poison, it is necessary to be sure that the poison penetrates freely. Hence experiments were made by using a fine hypodermic syringe to inject small amounts of very dilute solutions of poison into the pulp of sound apples. Blank injections and injections with tap water and distilled water produced even after six weeks no spreading from the point or line of puncture (the needle and liquid were sterilised before each puncture), but the surface became slightly depressed around each puncture, owing to the increased evaporation where the cuticle was broken. Injections of approximately one-tenth of a cc. of 1 per 100,000 solutions of copper, mercury and lead after six weeks looked superficially no different to blank injections, but except in a few cases where the needle evidently became blocked in puncturing, well-developed bitter pit areas were present around or at the base of the punctures having a diameter of 3 to 5 mm., and in the largest of these areas a few cells packed with starch grains were found.

However carefully the puncturing is done, the loose apple pulp cells block the needle more or less, so that it is impossible to inject accurately measured quantities. Owing to the physical differences between apple pulp and animal tissue, this method is in fact not suitable for exact quantitative investigations in this particular case, and hence was abandoned in favour of a more exact and controllable *modus operandi.*

The actual sensitivity of the pulp cells of apples to poison.

The method used was to remove around the equator of each apple fragments of the cuticle approximately a millimetre square at intervals of a centimetre, by means of a clean, sharp razor, and to float the apples in a litre of the dilute solution to be tested. Apples almost always float with their equatorial line submerged and horizontal. Controls were performed with each set of experiments. It was found with practice easy to remove fragments of the cuticle without injuring the cells beneath the epidermis. These fragments must be quite colourless and transparent. If they show any colour some of the subjacent cellular tissue has been removed. Such apples are denoted in the following pages as "prepared" apples, and very close examination with a lens is necessary to detect the fact that they have been prepared. If kept in moist air, the prepared spots undergo no change or sinking, and are unaffected even by a week's immersal in pure distilled water. Occasionally, however, and particularly in the case of Five Crown apples, wet rot may start at a prepared spot, but this is quite different from the bitter pit change, which is always ultimately characterised by dark-coloured or brown, dry, more or less shrivelled cells with brittle walls, even when produced by long immersal in a dilute poisonous solution. The pits are, in fact, often noticeably dry when the apples are taken out of the poisonous solution, and always become so after it has been kept in air. In wet rot, however, whether due to fungal hyphae or not, the tissue always seems to become soft and watery.

Owing to the exhaustion of the supply of unsprayed apples from my own orchard, some of the later tests were performed with purchased apples whose history was unknown, but which had in many cases obviously been sprayed. These were cleaned with a cloth and warm water, but this was not always sufficient to remove the poison adhering to the skin. In such cases the controls in water may show a well-developed pit under one or more of the prepared spots while the others are quite unaffected, and the results with increasing dilutions of poison will show more or less pronounced inconsistencies. This difficulty was most pronounced with the Five Crown apples, which also seem to be more affected by submersal in water than the other kinds used. In all such cases the experiments were repeated, and they are only given when consistent results were obtained with the first, second and even third trials. On this account shorter periods of immersal were used with the Five Crowns sorts. Apart from the necessity of using pure copper-free distilled water, care must be taken that the glass vessels used are chemically clean. The best method of assuring this was found to be by polishing them internally ($1\frac{1}{2}$ litre gas cylinders) with a damp cloth and precipitated chalk, and then rinsing well with tap water, and finally with distilled water. This method was as effective as coating the vessels internally with paraffin. A litre of solution was used to each apple, since this appears to be approximately equal to the total quantity of water used or stored by a fairly large apple during its development while attached to the tree.

Mercuric Chloride.—

Prepared Scarlet Nonpareils.—Floating on solution one week, and examined after three days in air. One gram $HgCl_2$ per 200,000 c.c. water. Large, deep brown pits at each prepared spot.

One gram per 1,000,000 of water. Pits similar, but not quite so deep. The Federal Analyst reported that " extremely faint but distinct indications of mercury were detected in the form of metallic mercury. The quantity present in each instance was less than approximately 1-100,000th part of one grain." The total bulks of " diseased " tissue were approximately 2 and 5 c.c. Hence the concentration in the affected tissue lay between one in 30 millions and one in 75 millions, i.e., very considerably less than in the solution outside. The poison has, however, to diffuse in through very narrow points of entry, and then spreads in the internal pulp in concentric hemispheres of decreasing concentration as far as the pit extends, so that at the outer margins the concentration will be much less than at the point of entry.

Prepared Jonathans.—Immersed one week. Examined after one week in air.

One per 10,000. Large spots extending deep into pulp, and some confluent.

One per 100,000. Pits smaller and each one distinct.

One per 500,000. Deep, well developed pits to each prepared spot.

One per 2,500,000. Pits not so deep or broad.

One per 25,000,000. Pits from 2 to 6 mm. diameter, and 2 to 4 mm. deep beneath each prepared spot.

Immersed one week and examined after two weeks in air.

One per 50,000,000. Distinct brown pits from 1-3 mm. deep beneath each prepared spot.

One per 100,000,000. Same as preceding, but pits a little fainter and shallower, and some spots showing a little superficial browning only.

One per 1,000,000,000. Three pits 2 mm. deep, two of prepared spots with a brown rim, rest no signs of poisoning.

One per 10,000,000,000. One prepared spot with faint brown rim, rest unaffected.

One per 100,000,000,000. No trace of any poisonous action.

In pure copper-free, distilled water, no diseased tissue at the prepared spots, pits or marks of any kind.

Copper Sulphate.—

Prepared Jonathans.—One week in solution, and examined after a week in air.

One gram in 100,000 c.c. (250 cc. of solution). Well developed pits up to ½ cm. diameter, and mostly 2-3 mm. deep.

One per 200,000. Pits well developed. The Federal Analyst reported, "No copper detected."

One per 500,000. Pits well developed, some nearly 5 mm. deep.

One per 1,000,000. Pits less developed, but some 3 to 5 mm. deep. The Federal Analyst reported, "No copper detected."

One per 2,500,000. Pits beneath each prepared spot, but none exceeding 2-3 mm. deep.

One per 25,000,000. Superficial browning to pits with dead tissue, not exceeding 1 mm. beneath most of the prepared spots.

One per 100,000,000. Slight superficial browning at some of the prepared spots.

One per 1,000,000,000. No signs of any poisoning.

Hence, although the pulp cells of apples are extraordinarily sensitive to copper sulphate, they are less so than to mercuric chloride. Nevertheless the traces of copper sometimes present in distilled water are sufficient to affect them. Thus a prepared apple was floated on 250 c.c. of water distilled in a copper vessel and tubes. The water was renewed daily for one week, and after two weeks in air distinct pits up to 3 mm. depth had developed beneath all the prepared spots. Similar apples on 100 c.c. of the same water for one week and on water distilled in glass vessels developed no perceptible pits.

All varieties are not equally sensitive, and Rome Beauties are, for instance, distinctly less sensitive than Jonathans. Thus after similar treatment and times on a solution of 1 gram per million of water, the pits were more superficial and not more than 1 to 2 mm. deep, and no trace of any poisonous action on this variety could be detected with solutions of 1 per 100 millions. There is, however, a possibility that the conditions under which an apple has been grown may affect its resistance to poison, and actual evidence of this is given later, so that apparent differences between varieties may not be as prominent in some cases as in others.

Lead Nitrate.—

Prepared Rokewoods.—One week in 1 litre of solution, and examined after two weeks in air.

One per 10,000,000. Pits 1-3 mm. deep beneath each prepared spot.

One per 100,000,000. From no effect to slight superficial browning.

One per 1,000,000,000. No perceptible signs of poisoning.

Prepared Jonathans.—One week in 1 litre of solution, and examined two weeks later.

One per 200,000. Pits from superficial to 5 mm. deep. The Federal Analyst reported, "No lead detected."

One per 1,000,000. Distinct pits up to 2 or 3 mm. deep under some, but not all of prepared spots. The Federal Analyst reported, "No lead detected."

Lead nitrate is evidently distinctly less poisonous in its action than mercuric chloride, and is slower in its action and penetration than the sulphate of copper. In the following tests with prepared Jonathans, after one week's immersal the apples were kept in air for nine weeks[1].

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[1] In all cases the apples after washing were kept in the same cleaned gas cylinders in which they had been tested. These keep the apples well aerated and yet in moist air without danger of infection. They keep for a remarkably long time under such circumstances without shrivelling or rotting.

One per 100,000 (250 c.c. of solution)[1]. Well developed, but small pits, none exceeding 3-4 mm. diameter and 1-2 mm. depth. Numerous minute black spots on skin, but the pulp quite sound.

One per 500,000. As above, but no spots on the skin.

One per 2,500,000. Pits barely exceeding 1 mm. depth, and not spreading laterally beyond the prepared spots.

One per 25,000,000. From superficial browning to a few pits 1 mm. deep.

One per 100,000,000. Superficial browning on most, but not all, of the prepared spots.

One per 1,000,000,000. No signs of any poisoning action on any of the prepared spots.

One point specially noticeable is, that with very dilute solutions, the quantity of solution is as important as its concentration. Thus a litre of 1 per 500,000 exercises the same action as 250 c.c. of 1 per 100,000, and a litre of 1 per 200,000, which contains twice as much poison as 250 c.c. of 1 per 100,000 also exercises a greater poisonous action when the same area of apple pulp is exposed to it for a sufficient length of time.

All varieties are not equally sensitive. Thus prepared Rome Beauties kept in the solution one week, and examined after two weeks, showed only superficial browning to pits under 1 millimetre deep in a solution of 1 per million, and no perceptible effect in a solution of 1 in 10 millions.

The influence of age.

In order to determine the influence of age upon the sensitivity to poison, young Jonathans about three weeks old were selected, averaging 3 cm. in length by 2 cm. in diameter. They were immersed in solutions of lead nitrate for one week, and after being kept in moist air for a week were examined.

Apples with the normal uninjured surface gave the following results with lead nitrate:—

One per 1000. Numerous small pits with irregular edges, mainly superficial, and none exceeding 1 mm. deep and 2 mm. diameter.

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[1] In all cases where not otherwise stated, 1 litre of the solution was used to each apple, which approximates to the amount of water an apple of 100 c.c. bulk may absorb from the tree during its development.

One per 10,000. From none to several mainly superficial pits, none exceeding $\frac{1}{2}$ mm. deep and 1 mm. diameter.

One per 100,000. No perceptible effect.

At this stage apples have the cuticle very feebly developed, the bloom absent, and the minute temporary breathing pores (stomata) have not yet been replaced by the larger adult ones (lenticels). The skin is therefore more or less generally permeable to poison, and the pits are developed without any relation to breathing pores. The permeability of the skin is also shown by the fact that in fairly dry air the apples after picking undergo a pronounced loss of weight in one day, and in three to seven days begin to shrivel.

With prepared apples the young pulp cells showed themselves to be very much more resistant than the pulp cells of adult apples.

One per 10,000. Strongly marked but mainly superficial pits beneath each prepared spot, none exceeding 2 mm. diameter and 1 mm. depth.

One per 100,000. Superficial layers browned and killed at each prepared spot, but no distinct pit formation.

One per 1,000,000. From no perceptible effect to distinct but entirely superficial browning (two to three layers of cells brown and dead).

One per 10,000,000. No perceptible effect.

In dry air the prepared areas show a tendency to cork formation, but not in water or in moist air. These results show that while in these young apples the skin is more readily permeable than in adult ones, the pulp cells are some hundred times more resistant to such a poison as lead nitrate. Hence sufficient poison might enter a young apple to produce internal poisoning when adult, without showing any signs of its presence at first, beyond hindering or preventing the solution of deposited starch grains. Later on the affected cells would die, not so much because the poison increased in amount as because the resistance of the cells decreased with age. It is worthy of note in this connection that these young Jonathan apples three or so weeks old contain plenty of active chloroplastids particularly in the outer layers, but no starch grains either in the healthy pulp or superficial cells, or in the poisoned pit cells.

The starch grains are deposited at a later period and then dissolved during ripening.

Bases generally present in soils.

Although the foregoing metallic poisons are found in certain soils they are usually of limited occurrence, although in the soils of orchards that have been frequently and freely sprayed with poisonous metallic compounds, appreciable quantities may be retained in the soil. As is well known, fertile soils have a pronounced retentive action upon many metallic poisons, and particularly those which like mercury combine with organic matter (proteids, etc.). Nevertheless an abundant but feebly poisonous base can exercise the same effect as a scarce but highly poisonous one if absorbed in sufficient amount.

The bases used were magnesium, calcium, barium and potassium, as the sulphates and chlorates.

Magnesium Sulphate.—

Prepared Five Crowns.—Immersed three and a-half days in solution, and examined after 14 days in air.

One per 1000. Pits 3-12 mm. diameter; 2-5 mm. deep.

One per 10,000. Pits 2-5 mm. diameter; 2-3 mm. deep.

One per 100,000. Pits 2-3 mm. diameter; 1-2 mm. deep

One per 1,000,000. Slight superficial browning only.

One per 10,000,000. No perceptible poisoning effect.

Zinc sulphate gave practically identical results, except that the poisoning effect was more distinct with 1 per 1,000,000, and was perceptible in this dilution even with Rome Beauties.

This sensitivity was quite unexpected in the case of magnesium sulphate, but the apples were purchased ones of unknown history, and Five Crowns appear to be somewhat sensitive to prolonged immersal in water. Another batch, however, gave closely similar results, but other varieties were much less sensitive.

Prepared Rome Beauties.—One week in solution and examined after one week in air.

One per 1000. From superficial browning to pits 2 mm. deep.

One per 10,000. From superficial browning to pits 0.5 mm. deep.

One per 100,000. No perceptible poisoning effect.

Calcium sulphate gave exactly similar results to magnesium sulphate with Rome Beauty apples.

Barium Chlorate.—

Prepared Jonathans.—In solution for one week, and examined after two weeks in air.

One per 10,000. Pits 1-4 mm. diameter and 1-3 mm. deep.

One per 100,000. From superficial browning to pits 1 mm. deep.

One per 1,000,000. No perceptible development of pits or browning.

Prepared Rome Beauty.—One week in solution, one week in air.

One per 1000. Dark, well-developed pits 1-3 mm. deep.

One per 10,000. From superficial browning to pits 1 mm. deep.

One per 100,000. From slight superficial browning to no effect.

One per 500,000. No perceptible poisoning action.

Potassium Chlorate.—

Prepared Jonathans.—One week in solution, and examined after two weeks in air.

One per 10,000. From superficial browning to slight pit formation, none exceeding 1 mm. deep.

One per 100,000. No perceptible poisoning action.

Prepared Rome Beauty.—In solution one week and air one week.

One per 1000. From superficial browning to pits 2 mm. deep.

One per 10,000. From slight superficial browning to pits 0.5 mm. deep.

One per 50,000. No perceptible poisoning action.

Of these four salts the barium one is most poisonous[1], the magnesium and calcium next, while potassium is one of the least poisonous. The last three are all essential elements of the plant's food, but as we shall see later they do not exercise the same poisonous action when they are present jointly in the proper proportions, as when present singly. In addition, with the more dilute solutions, symptoms of poisoning (browning of cells, etc.) usually do not show until after the removal from the solutions, and even although the apples are kept in moist air, there is a possibility of some concentration taking place. This is, however, just what occurs under natural conditions whenever a plant absorbs any substance which it does not use, or does not use as rapidly as it absorbs it, both of which cases are of common occurrence in nature. In any case the artificial bitter pit tissue has the same peculiar dry, corky appearance of natural bitter pit, whether it is produced by poisonous heavy metals or metals of the alkali and alkaline earth groups, and whether it is produced in a watery solution or not. Mere superficial examination is sufficient to distinguish it from the soft brown rot produced by fungi, strong doses of poison, etc. The browning of the tissue, the brittle cell walls and the tendency to shrinkage and cracking are not shown when the pits are produced by relatively strong doses of acid, but are when very dilute solutions are used, i.e., when the passage from life to death is gradual instead of sudden. Hence the appearance of certain features of bitter pit is rather a characteristic of life than of death. If a peeled apple is soaked in a solution of 1 per 100,000 of mercuric chloride, a brown zone travels slowly inwards, preceded by a pale zone a few millimetres broad. In a 1 per 10,000 solution, the pale zone is much narrower, and contains living cells at its inner border, whereas in the browned tissue all are dead. The brown colour is evidently not due to any ferment action, or it would not be produced in the presence of mercury, but is possibly the result of the direct oxidation of a chromogen produced or liberated during the death of the pulp cells.

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[1] Mr. Wilkinson informs me that barium is more commonly present in soils than is generally supposed.

Although gold is never present in great abundance, traces of it in soluble form occur in the sea, and possibly also in some soils and in soil waters.

Gold Chloride.—

Prepared Yates' Pippin.—Four days in solution, and examined after one week in air.

One per 10,000. Pits 2 to 5 mm. deep.

One per 100,000. Pits 1 to 2 mm. deep.

One per 1,000,000. Pits superficial to 1 mm. deep.

One per 10,000,000. Superficial browning only.

One per 100,000,000. No perceptible signs of poisoning.

One per 1,000,000,000. No perceptible signs of poisoning.

In the 1 per 10,000 solution the contact with organic matter and the presence of light causes gold to be deposited, the liquid becoming golden in reflected, and green in transmitted, light. In the 1 per 100,000 the gold separates in a still finer state of subdivision, the liquid becoming a clear purple colour, barely perceptible in the 1 per 1,000,000 solution. Gold is deposited on the skin of an apple in a 1 per 10,000 solution, and can be removed by rubbing with a cloth. In the 1 per 10,000 and the 1 per 100,000 solutions the prepared spots are black on the surface, and a deeper brown than usual within. This decomposition of the gold chloride at the surface may explain why the pulp cells appear to be so much less sensitive to gold chloride than to mercuric chloride or copper sulphate.

The action of poisonous plant products.

Since formaldehyde is one of the primary products of the photo-synthesis of carbon dioxide, and since young apples contain chloroplastids capable of active photo-synthesis, a fact which was determined by means of the Bacterium method, the possibility needed consideration of a self-poisoning by the continued production of formaldehyde, while its polymerization to sugar or starch was for some reason suppressed.

Sound adult Scarlet Nonpareil apples, which had been for three months in cool storage were floated on a 1 per cent. solution (1 c.c. of 40 per cent. in 100 c.c. of water) for one week. They were covered with dark, irregularly distributed sunken areas, but even after three weeks the marks were superficial, and did not extend into the pulp. No trace of formaldehyde could be detected in them, the poison, being volatile, having long since evaporated. In a 1 per 1000 solution, numerous small spots appeared, and in a 1 per 10,000 a few minute ones, but these were also entirely superficial. Solutions of 1 in 20,000 and 1 in 100,000 produced no effect.

Formaldehyde.—

Prepared Yates' Pippin.—Three days in solution, and examined in three days.

One c.c. of 30 per cent. solution in 100 of water. Pits from 5-6 mm. deep.

One per 1000. Pits 4-5 mm. deep.

One per 10,000. Pits superficial to over 1 mm. deep.

One per 100,000. No perceptible signs of poisoning.

Apples are therefore very much less sensitive to formaldehyde than might have been expected, and a relatively considerable accumulation of it would be necessary to poison the pulp cells. Since it is a volatile substance it could hardly produce a permanent arrest of ferment action on the starch grains. The same objection applies to the following alkaloids, which are produced by some plants, but not by apples.

Alkaloids.

To many plants, and more especially to those which produce them, alkaloids are comparatively non-poisonous, and some fungi may even use them as food. Generally speaking, the alkaloids are rather nerve and muscle poisons than protoplasmic poisons, and a plant which has no nerves or muscles may or may not be sensitive to alkaloids, which are deadly poisonous to warm-blooded animals. Strychnine appears to be the most poisonous of the alkaloids to those plants which are sensitive to alkaloids. In this case apples appeared to show a quite unusual and unexpected general sensitivity to poisonous alkaloids.

Brucine Nitrate.[1]—

Prepared Five Crown apples.—Three and a-half days in solution, examined after one week in air.

One per 1000. Pits ½ to 1 cm. diameter, and 2 to 5 mm. deep.

One per 10,000. Pits ½ to 1 cm. diameter, and 1 to 4 mm. deep.

One per 100,000 Pits 2 to 5 mm. diameter, and 1 to 3 mm. deep.

One per 1,000,000. Pits 1 to 2 mm. diameter, and ½ to 1 mm. deep.

One per 10,000,000. No perceptible poisoning action.

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[1] Brucine nitrate dissolved in very dilute HNO_3 and solution neutralized with NH_4HO If the acid is sufficiently dilute, no brownish red colour is produced.

One per 100,000,000. No perceptible effect.

Morphine sulphate gave exactly similar results to the above.

With strychnine sulphate the following results were obtained:—

One per 1000. Pits ½ to 1 cm. diameter, and 2 to 5 mm. deep.

One per 10,000. Pits ½ to 1 cm. diameter, and 2 to 4 mm. deep.

One per 100,00. Pits 2 to 5 mm. diameter, and 1 to 3 mm. deep.

One per 100,000. Pits 2 to 5 mm. diameter, and 1 to 3 mm. deep.

One per 10,000,000. No perceptible poisoning action.

Similar results to those with strychnine sulphate were obtained with atropine sulphate.

If the apples are used, as these were, late in the season, it is necessary that they should not be kept long after removal from cool storage before testing. Otherwise the pulp cells have so delicately balanced a vitality that imperceptible or "spontaneous" causes may upset the balance, and in such cases it is difficult to obtain regularly consistent results obviously due to the poison used.

The following tests were performed with Rome Beauties freshly taken from cool storage, and after washing prepared as usual for testing by the removal of square millimetres of cuticle a centimetre apart around the equators of the apples. The apples were floated for one week in the solution, and kept for one week in air before examination.

Brucine Nitrate.—

One per 10,000. Pits 1 to 2 mm. deep.

One per 100,000. Superficial browning to pits 1 mm. deep.

One per 1,000,000. No effect to slight superficial browning.

One per 10,000,000. No perceptible effect.

Strychnine Sulphate.—

One per 100,000. Pits 1 to 2 mm. deep.

One per 1,000,000. From superficial browning to pits barely exceeding 0.5 mm. in depth.

One per 10,000,000. No perceptible poisoning action.

Apparently therefore Five Crown apples are more sensitive to alkaloids than Rome Beauties, but strychnine sulphate and morphine sulphate are relatively more poisonous to Rome Beauties as compared with brucine nitrate than to Five Crowns.

The sensitivity of different organisms to strychnine sulphate varies greatly. Thus Andrews[1] found that a concentration of 1 per 100,000 rapidly kills *Volvox*, whereas a concentration of 1 per 1,000,000 left *Diatoms*, *Desmids*, and blue green *Algae* unaffected, and a solution of 1 in 250 was required to kill ordinary fresh water and marine *Algae*.

Acids.

The commonest acid produced by plants apart from carbonic acid is perhaps oxalic acid. but citric acid may be produced by certain fungi and by fruits, nitric acid may be produced by nitrifying soil bacteria, and sulphuric acid by certain sulphur bacteria.

Oxalic Acid.—

Prepared Five Crown apples.—Three and a-half days in solution, and examined after one week in air.

One per 1000. Pits 4 to 12 mm. diameter, and 3 to 6 mm. deep.

One per 10,000. Pits 3 to 8 mm. diameter, and 2 to 4 mm. deep.

One per 100,000. Pits 1 to 4 mm. diameter, and 1 to 2 mm. deep.

One per 1,000,000. From no perceptible effect to superficial browning.

One per 10,000,000. No perceptible effect.

Prepared Rome Beauty.—One week in solution, and examined after one week in air.

One per 10,000. Pits 1-3 mm. deep.

One per 100,000. From superficial browning to pits under 1 mm. deep.

One per 1,000,000. From no effect to slight superficial browning.

One per 5,000,000. No perceptible effect.

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[1] Proc. of the Indiana Academy of Science, 1905, p. 195.

Citric Acid.—

Prepared Rokewood Apples.—In solution one week, and examined after one week.

One per 10 000. Pits 1 to 4 mm. deep.

One per 100,000. From superficial browning to pits 1 mm. deep.

One per 1,000,000. No perceptible effect.

Prepared Rome Beauty Apples.—In solution one week, and examined after one week.

One per 10,000. Small pits, few exceeding 1 to 3 mm. deep.

One per 100,000. From superficial browning to pits 1 mm. deep.

One per 1,000,000,000. No perceptible effect.

Nitric Acid.—

Prepared Five Crown.—Three days in solution, and examined after one week in air.

One per 10,000. Large deep pits to each prepared spot.

One per 100,000. Pits under 5 mm. diameter and 3 mm. depth.

One per 1,000,000. Pits small, superficial, none over 1 mm. deep.

One per 10,000,000. Superficial browning only.

One per 100,000,000. Doubtful to no perceptible effect.

One per 1,000,000,000. Doubtful to no perceptible effect.

Prepared Rome Beauty.—One week in solution and one week in air.

One per 10,000. Pits 1-3 mm. deep.

One per 100,000. Superficial browning to pits 1 mm. deep.

One per 1,000,000. Doubtful to no perceptible effect.

One per 10,000,000. Doubtful to no perceptible effect.

These apples were wiped and had a good bloom, but a few small brown spots appeared on the general surface with a concentration of 1 per 10,000, none with lesser concentrations. An apple with the bloom scraped off from a line around the circumference showed a line of pits up to 5 mm. deep, but only beneath lenticels after being in a solution of 1 per 1000 for one week, and over the general surface most of the lenticels showed as small brown spots none exceeding 1 mm. diameter.

The cuticle and bloom of apples is therefore as impermeable to acids as it is to metallic poisons. Another point worthy of note is that with the strong acid solutions, the pits are at first pale in colour, the dead tissue softer and more watery, slowly becoming a deeper brown on keeping in air.

Sulphuric Acid.—

Prepared Five Crowns.—One week in solution and three weeks in air.

One per 10,000. Pits confluent and 5 mm. deep.

One per 100,000. Pits smaller, up to 3-4 mm. deep.

One per 1,000,000. Pits smaller, up to 1-3 mm. deep.

One per 50,000,000. Faint superficial browning in some cases.

One per 500,000,000. No perceptible effect.

Prepared Rome Beauties.—In solution one week, and examined after one week in air.

One per 10,000. Pits 1-3 mm. deep.

One per 100,000. From superficial browning to pits 1-2 mm. deep.

One per 1,000,000. All the prepared spots browned superficially, but no distinct pits.

One per 10,000,000. No perceptible effect.

After floating Rome Beauties with a good bloom and normal skin on a solution of 1 per 1000 for 14 days, and then keeping for two weeks in air, a few minute spots appeared on the surface, but no pits, and the pulp remained quite sound. Evidently, therefore, the normal skin of this variety is still more impermeable to sulphuric than it is to nitric acid, and the latter acid being more volatile will more readily enter through the lenticels without necessarily displacing the air in their pores by liquid. This is a point of theoretical rather than of practical importance, since although appreciable traces of nitric acid may be present in the air after thunderstorms, they are hardly in sufficient amount to affect apples during the time they remain present.

The specific resistance to poisons.

The foregoing results show clearly the extraordinary sensitivity of the pulp cells of apples to poisons. They are in fact more sensitive to poisons than any other plant or animal cells hitherto examined. The resistance of the apple as a whole to the external application of poison will depend upon its age, upon the development of the cuticle and bloom, and upon the variety of apple.

In regard to the influence of age, the inherent resistance of the pulp cells progressively decreases as the apple becomes adult. In cool storage the sensitivity of apples to poison is only slightly increased even after five months. After removal from cool storage, however, the sensitivity rapidly increases after the first week or two.

Apples with an unbroken skin and good bloom may be immersed in poisonous solutions of far greater concentration than that required to kill the pulp cells. An adult apple is in fact a most delicate but marvellously well-protected mechanism. The young apple is less well-protected externally, but its pulp cells have a greater inherent resistance to poison. A young apple could, in fact, absorb sufficient poison to kill its cells when adult without being affected at first while it was young.

For the above reasons it is difficult to make exact comparisons between different varieties, but with apples of equal age, the sensitivity of the pulp cells to metallic poisons is in the following order:—Five Crown, Jonathan, Scarlet Nonpareil, Rokewood, Rome Beauty, Yates' Pippin[1], the last-named being much more resistant than the first. There are, however, naturally some exceptions with specific poisons. Thus Rokewoods and Yates' Pippins appear to be less sensitive to lead than Jonathans, and Yates' Pippins were also much less sensitive to copper sulphate. Similarly brucine nitrate was apparently slightly more poisonous to Rome Beauties than strychnine sulphate, but with Five Crowns this was reversed. Rokewood and Rome Beauties showed almost exactly the same sensitivity to citric acid, but not to more active poisons.

A very interesting fact noticed was that as a general rule with minimal concentrations of all poisons, the poisonous action usually disappears first from the more exposed side of the apples as indicated by the colour of the skin. Thus the prepared areas on the paler shaded side may still show faint but distinct signs of poisoning, while those on the red side are quite unaffected. This greater resistance of the superficial pulp cells on the exposed side to poison is not due to the cuticle or bloom since they have been removed prior to the test. There is no perceptible difference in the thickness of the cell walls, but the pulp cells in some cases at least were slightly smaller on the exposed side, and hence presumably contained a relatively greater bulk of protoplasm to be poisoned. It can often be noticed that when an apple is strongly exposed on one side, and shaded on the other, it develops a greater radius on the shaded side. Apparently this is partly, at least, due to the cells becoming larger on that side. Dr. White noticed that bitter pit was commoner on the shady side of the fruit or tree than on the exposed side, and suggested that the moisture would persist longer on the shaded side and so favour the entry of spray poisons. Apparently, however, the exposed side of an apple actually retains a greater resistance to poisons than does the shaded side.

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[1] Yates Pippin appears to be comparatively immune to bitter pit under natural conditions, at least Dr. White found no apples of this variety affected by it in any of the orchards examined by her.

The influence of ionization and of the respective ions.

In the case of all compounds which undergo dissociation when dissolved in water, the poisonous action is the result of the joint action and non-action of the different ions and of the undissociated molecules of the compound. A salt may be poisonous on account of either the basic or the acidic radicle composing it being poisonous, or both of them[1]. Further, if one of the ions is much more poisonous than the other, or than the undissociated salt, then increasing dilution, since it increases the relative omount of dissociation, will not produce a decreased poisonous action in direct but in decreasing ratio to the dilution. To some extent this may explain the excessive dilutions at which such salts as mercury, copper, etc., may remain poisonous. More exact comparisons can only be made by calculating the poisonous concentrations in terms of the molecular weights of the different compounds. This is done in the following table, in which the first column gives the poison used, the second the variety of apple, the third the duration of exposure to the poisonous solution, the fourth the lowest concentration at which signs were shown of any distinct poisoning of the pulp cells in prepared apples, and the fifth this concentration in molecular equivalents, so that a comparison is possible between the poisonous action of equal number of molecules :—

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[1] For literature see Pfeffer's Physiology, vol. ii., p. 273. (Eng. Trans.)

Poison.	Kind of apple.	Exposure in days.	Poisonous limit* in grams per c.c. of water	Numerical Poisonous action on an equi-molecular basis.
Mercuric chloride	Jonathan	7	1 per 1,000,000,000	271,000
Mercuric chloride	Yates' Pippin	7	1 per 100,000,000	27,100
Copper sulphate	Jonathan	7	1 per 100,000,000	24,900
Copper sulphate	Yates' Pippin	7	1 per 1,000,000	249
Lead nitrate	Jonathan	7	1 per 25,000,000	8275
Lead nitrate	Yates' Pippin	7	1 per 2,500,000	827
Lead nitrate	Rokewood	7	1 per 10,000,000	3310
Lead nitrate	Young Jonathans	7	1 per 1,000,000	331
Lead arsenate	(P. O'Gara)	on tree	1 per 13,000,000**	5876
Gold chloride	Yates' Pippin	4	1 per 10,000,000	3020
Zinc sulphate	Five Crown	3½	1 per 2,500,000	717
Zinc sulphate	Rome Beauty	7	1 per 1,000,000	287
Arsenic (trioxide?)	Jonathan	4	1 per 500,000***	98.8
Magnesium sulphate	Five Crown	3½	1 per 100,000	24.6
Magnesium sulphate	Rome Beauty	7	1 per 10,000	2.4
Magnesium sulphate	Yates' Pippin	7	1 per 5,000	1.2
Barium chlorate	Jonathan	7	1 per 100,000	30.3
Barium chlorate	Rome Beauty	7	1 per 10,000	3.0
Barium chlorate	Yates' Pippin	7	1 per 10,000	3.0
Calcium hydrate	Jonathan	7	1 per 5,000	0.37
Potassium chlorate	Jonathan	7	1 per 10,000	1.2
Potassium chlorate	Rome Beauty	7	1 per 10,000	1.2
Formaldehyde	Yates' Pippin	3	1 per 10,000	1
Chloroform	Jonathan	7	1 c.c. per 100,000	7.9

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*The concentration given is that at which quite a distinct poisonous action is still perceptible, and not that at which it is just fading out, one litre of solution being used to each apple.

**Estimated from P. O'Gara's analyses of the percentage of arsenic in dead pit tissue produced by arsenate of lead.

***Estimated from percentage of arsenic present in strongly poisoned tissue. The real limit is probably much lower.

Poison.	Kind of apple.	Exposure in days.	Poisonous limit* in grams per c.c. of water.	Numerical Poisonous action on an equi-molecular basis.
Brucine	Rome Beauty	7	1 per 25,000	11.9
Brucine nitrate	Five Crown	3½	1 per 1,000,000	476
Brucine nitrate	Rome Beauty	7	1 per 100,000	47.6
Morphine sulphate	Five Crown	3½	1 per 1,000,000	381
Strychnine sulphate	Five Crown	3½	1 per 1,000,000	430
Strychnine sulphate	Rome Beauty	7	1 per 1,000,000	430
Strychnine sulphate	Yates' Pippin	7	1 per 25,000	10.8
Atropine sulphate	Five Crown	3½	1 per 1,000,000	385
Oxalic acid	Five Crown	3½	1 per 100,000	9
Oxalic acid	Rome Beauty	7	1 per 100,000	9
Citric acid	Rokewood	7	1 per 100,000	19.2
Citric acid	Rome Beauty	7	1 per 100,000	19.2
Citric acid	Yates' Pippin	7	1 per 10,000	1.9
Nitric acid	Five Crown	3	1 per 1,000,000	63
Nitric acid	Rome Beauty	7	1 per 100,000	6.3
Sulphuric acid	Five Crown	7	1c.c. per 10,000,000	532
Sulphuric acid	Rome Beauty	7	1c.c. per 1,000,000	53
Ammonia	Jonathan	7	1c.c. per 10,000	0.4

Generally summarising the means of the foregoing results, the substances tested may be grouped in the following order as regards their toxicity to adult apples. Mercuric chloride, copper sulphate, lead nitrate, gold chloride, zinc sulphate, sulphuric acid, the sulphates and nitrates of brucine, strychnine, atropine and morphine, nitric acid, barium chlorate, magnesium sulphate, citric acid, oxalic acid, chloroform, potassium chlorate, formaldehyde, ammonia, calcium hydrate. It follows also from the table that the poisonous action of the mercuric, cupric, lead and gold salts is due almost solely to their basic components. The comparison between barium and potassium chlorate shows that barium as a base is distinctly poisonous to apples, whereas the poisonous action of magnesium sulphate is largely due to its dissociated sulphate ions. To a lesser extent the same is true for the salts of alkaloids, but the bases in this case do appear to have themselves an inherent and fairly pronounced poisonous action. Strychnine was much more poisonous to Rome Beauties than the other alkaloids. The relatively feeble poisonous action of oxalic acid as compared with sulphuric acid may be partly due to the lesser dissociation of its hydrogen ions, and partly to its displacing bases less readily in the protoplasm of the pulp cells than sulphuric acid. Either the latter reason or a greater ease of penetration may explain why citric acid appears to be more poisonous than oxalic acid, or the oxalic acid may be precipitated to some extent without injury resulting. The almost innocuous character of calcium hydrate (limewater) is due to the carbon dioxide from the respiring pulp cells precipitating the calcium ions as chalk.

It is worth noting in this respect that the order of toxicity in the list above differs very widely on a quantitative molecular basis from what it would be in the case of an ordinary animal. This is especially shown in the relative positions of the alkaloids, and heavy metals, in the position of sulphuric acid, in citric acid preceding oxalic, and in magnesium sulphate preceding formaldehyde and ammonia. In animals, however, any poison which injures one organ may cause the death of the whole organism, whereas in plants, the effects of poisoning may be quite localised, and the death of a leaf by poisoning may not affect the plant more than the mere removal of the leaf would do, while the death of a fruit killed by poison may actually be of benefit to the mother plant, and economise its food supplies.

Naturally if both kation and anion are poisonous, a salt may be more poisonous than either of its ions applied singly. Thus brucine is sparingly soluble in water, but a solution in water only showed distinct signs of being poisonous to the pulp cells of Jonathan and Rome Beauty apples in a concentration of 1 in 25,000, doubtfully so in the case of 1 per 100,000, and none at all in the case of 1 per 1,000,000. The sulphate was, however, feebly but distinctly poisonous down to concentrations of 1 per 100,000.

Further, a mixture of poisonous salts may be less poisonous than either salt singly. In some cases the reason for this is obvious. For instance, a mixture of 303 cc. of 1 per 100,000 barium chlorate and 246 cc. of magnesium sulphate 1 per 100,000, is slightly less poisonous than the last solution applied singly. This is simply because the barium is precipitated as the insoluble sulphate, and the chlorate ions of the magnesium salt remaining are less toxic than the sulphate ions.

In the same way the presence of a sulphate in the cells will protect them against the toxic action of barium. Thus prepared apples floated for two days on a 1 per 10,000 solution of potassium sulphate and then on a 1 per 10,000 solution of barium chlorate for five days, showed only doubtful or no signs of poisoning, whereas after one week on 1 per 10,000 of potassium sulphate slight, and after one week on 1 per 10,000 of barium chlorate distinct, signs of poisoning were produced.

Even where no precipitation takes place, two salts jointly may not exercise any greater toxic action than either salt singly when in considerable dilution, although the total concentration is doubled with the mixtures of the two salts. This is well shown by the following results:—

Prepared Rome Beauties.—One week on solution, and examined after one week.

Barium chlorate, 1 per 10,000. From superficial browning to pits 1 mm. deep.

Barium chlorate 1 per 10,000, and potassium chlorate 1 per 10,000. From superficial browning to pits 1 mm. deep.

Potassium chlorate, 1 per 10,000. Superficial browning to pits 0.5 mm. deep.

Potassium chlorate 1 per 10,000, and magnesium sulphate 1 per 10,000. Superficial browning to pits 0.5 mm. deep.

The addition of a poisonous anion to a dilute toxic solution may even decrease the poisonous action of the mixture if it diminishes the amount of dissociation of a highly toxic kation. This is probably the explanation of the following results in which the addition of citric acid diminished the toxicity of copper sulphate, and the addition of sulphuric acid to copper sulphate produced no increase, but if anything a slight decrease of toxicity. The materials and times were as in the experiments above[1].

Copper sulphate, 1 per 1,000,000. Pits 1-2 mm. deep.

Copper sulphate 1 per 1,000,000, and sulphuric acid 1 per 2,000,000. Pits mostly just over 1 mm. deep.

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[1] Mr. Rivett informs me that the decrease in the concentration of copper ions would be much greater in the presence of citric acid than in the presence of an equivalent amount of sulphuric acid. The decrease is in fact so great that no copper hydroxide can be precipitated by caustic alkali.

Copper sulphate 1 per 1,000,000, and citric acid 10 per 1,000,000. From slight superficial browning to pits 1 mm. deep.

The nature of toxicity.

It is generally assumed that the toxicity of the heavy metals is due to their combining with the proteids of protoplasm, and that they are toxic in great dilution because the protoplasm has the power of absorbing and accumulating them in greater concentration than in the liquid outside. To some extent this is true, but nevertheless the foregoing experiments have shown that pulp cells poisoned by mercuric chloride may not contain this poison in a concentration of more than 1 in 30 to 100 millions, and possibly even less. It must be remembered, however, that the adult pulp cells of apples have only a thin layer of protoplasm, and that if this is killed at any point, however small, the death of the whole cell follows for physical reasons, in much the same way that a balloon collapses when pricked by a pin.

Certain cases of toxicity appear to be due to the removal by displacement or ionic interchange of the kations of metallic physiological salts present in the cell, such as calcium nucleoproteate. Thus Loew[1] has shown that various substances which precipate calcium (sodium fluoride, potassium oxalate) are poisonous to *Spirogyra*, and apparently act by removing the calcium from the nucleo-protein acids of the nucleus.

Similarly Loeb[2] showed that sodium chloride was poisonous to the eggs of a certain fish, but not when calcium was present in the external solution, and according to Loew[3] this action would be due to the removal of calcium in the one case, and its non-removal in the other. It is possible that the feebly poisonous action of potassium salts might be due to their displacing calcium or magnesium from the protoplasm of the pulp cells of apples, but if so it is difficult to understand why the addition of a potassium salt to a magnesium one does not increase the poisonous action, but if anything has the reverse effect. It may be that since magnesium and potassium are present inside the cell, the presence of both outside the cell approximates more closely to a physiologically balanced solution, and produces less protoplasmic disturbances than when one alone is present outside the cell. Taking as a definition of a toxic substance that it is one which in relatively small amounts injures or kills the cells in detail, or the living organism as a whole, all such substances may be termed toxic so far as apples are concerned, independently of what the details of their action may be.

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[1] Bull. Coll. Agric., Tokyo., Imp. Univ., vii. 1906., p. 18.

[2] Arch. f. f. ges. Physiol. 107, p. 252., 1905.

[3] See also Osborne, Proc. Physiol. Soc. xxxiii, 1905, p. 1. and 1906, xxxiv., p. 84.

Taking the poisonous dose of mercuric chloride as compared with the body weight of a man to be 1 per 100,000, the pulp cells of apples are certainly 100, and possibly much more than 1000, times as sensitive as man, comparing the quantity required to poison a given amount of material. With alkaloids the reverse is the case. Curiously enough, formaldehyde is less poisonous to apples than almost any other substance tried, and is certainly far less relatively poisonous to apples than it is to animals. No evidence of any polymerization could be detected, so that evidently the adult pulp cells have developed a special resistance to a substance which they themselves produce when young and assimilating.

The action of gases and volatile substances.

The possibility of poisons in volatile form reaching apples needs consideration, and accordingly a variety of substances more or less likely to be present in air were tried.

Ammonia.—Strong ammonia vapour rapidly blackens the skin of sound Jonathan apples, more dilute vapours brown the surface of Jonathans and Sturmer Pippin, and produce small pits within three days, mainly beneath breathing pores. For quantitative estimation of the toxicity, solutions of ammonia (0.88 sp. gr.) in varying amounts of water were used. Thus with Jonathan with a sound, uninjured skin after 1 week in 1 c.c. of 0.88 in 200 cc. of water, within a week numerous brown spots 1-5 mm. diameter, and from superficial to 3-4 mm. deep appeared, but in a litre of 1 per 2000 cc., no spots or pits formed even after one week's immersal and five weeks in air.

Prepared Jonathans.— One week in solution, and examined one week after removal from solution.

One c.c. per 2000. Pits from superficial to 2-3 mm. deep.

One c.c. per 20,000· Superficial browning to pits 1 mm. deep.

One c.c. per 100,000 No effect to slight superficial browning.

One c.c. per 1,000,000. No perceptible effect at any time.

Ozone.—Each apple (Jonathans and Sturmer Pippins) was placed in a 1½ litre gas cylinder, charged with ozone by the silent discharge of high-tension electricity (10-inch spark coil) for two minutes daily for three days[1]. No perceptible effect was produced except that many of the breathing pores became more prominent.

The experiment was then repeated, charging three times daily for five minutes at a time for three days (a total of 45 minutes charging). The apples were covered with small spots and pits. The latter in one week were 1-2 mm. diameter and 2-3 mm. deep. These were almost entirely developed under breathing pores, but a few formed under the unbroken skin. Closely similar effects were produced by one charging of an hour's duration. The air was neither acid nor alkaline, and the ozone rapidly disappeared in contact with apples, no trace being detectable with starch and potassium iodide paper after 10 to 24 hours. Neither ozone nor ammonia are, however, likely to be present under natural conditions in sufficient amount, and for a sufficient length of time, to affect apples, except under most unusual circumstances.

Iodine.—A solid substance which is volatile, may, however, affect apples at some distance. Thus a Jonathan apple was placed in a closed 1½ litre gas cylinder one foot distance from 5 milligrams of iodine. In five days the iodine had sublimed, and in seven days the apple was covered with small dark spots. No smell of iodine was perceptible, but starch paper placed on the apple in the cylinder was tinged faint blue in 20 minutes. After two weeks in air, some of the spots had enlarged to pits 1 to 2 mm. diameter, and 1 mm. deep.

On repeating the same experiment, keeping the cylinder closed for 14 days, two weeks later many of the spots developed into pits 1 to 2 mm. deep, and a few larger discoloured areas developed beneath or between breathing pores to a depth of 3 to 4 millimetres. About the same effect was produced by placing apples six inches away from 40 milligrams of iodine for two days, but the spots appeared much sooner.

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[1] The apples were removed during each charging, since the silent discharge if long continued, produces brown spots and areas of variable depth, particularly if the apples touch the glass, or from the point of suspension if this affords a ready path for the current.

In the case of other volatile substances such as prussic acid, the diffusion is so rapid that the poisoning of the pulp takes place generally unless the correct time of exposure is found to produce pits. Thus one and two days' exposure to diluted hydrocyanic acid killed the pulp throughout. After six hours' exposure irregular brown areas of pulp appeared beneath the skin, some becoming sunken and pit-like, and a few brown patches radiated from the centre, unconnected with the surface.

Chloroform.—Normal Jonathan apples kept in a 1 per 1000 solution for three days, developed numerous large and small spots and pits, and in many cases a white "efflorescence" appeared on the skin, due to the partial solution of the bloom. In 1 per 100,000 even after one week no pits or spots were found, although a faint smell of chloroform was perceptible on opening the cylinder.

Prepared Jonathan Apples.—Examined after two weeks in air.

One per 1000 (three days). Large, deep pits, with typical brown, spongy, shrivelled bitter pit cells.

One per 10,000 (one week). Pits 2-5 mm. deep.

One per 100,000 (one week). Pits 1-3 mm. deep.

One per 1,000,000 (one week). No perceptible signs of poisoning.

Arseniuretted Hydrogen.—Whenever arsenic compounds are in contact with organic matter, and particularly in the presence of certain fungi, there is a possibility of the evolution of arseniuretted hydrogen gas. The conditions for the development of minute traces of arseniuretted hydrogen gas, are present in any orchard heavily sprayed with arsenical compounds, particularly during close, moist weather.

Normal Jonathan apples were exposed each in a 1500 cc. gas cylinder to the arseniuretted hydrogen from 1 gram As_2O_3, and after keeping in air two weeks to allow all free gas to escape, forwarded for analysis[1].

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[1] During Mr. Wilkinson's absence these tests were performed by Mr. Willgerodt, using the very delicate Gutzeit test for arsenic.

Six Hours' Exposure.—After two weeks numerous brown spots and deep pits of variable size.

Customs' Analyst:—"No arsenic detected, but the extract frothed over owing to a mishap, before the test was quite completed. If any arsenic was present it was less than in the following cases."

One Day's Exposure.—General browning and two large dead areas 2 to 4 mm. deep.

Customs' Analyst:—"The total arsenic content of the apple 'Q' was equal to about 0.05 mg. arsenious acid (As_2O_3), or 1-3300th of a grain."

Two Days' Exposure.—Whole superficial layer soft, brown and dead to a depth of 5 to 10 mm., a little dead tissue also radiating from the core into the outer pulp.

Customs' Analyst:—"Apple 'R' contained a slightly larger amount of arsenious acid than apple 'Q.'"

Four days' Exposure.—Same effect as before, but more pronounced. The volume of the apple was 104 cc., and approximately half of the pulp was dead.

Customs' Analyst:—"The apple 'S' contained the largest amount, equal to about 0.10 to 0.15 mg. As_2O_3 (1-1600th to 1-1000th of a grain)."

The arsenic was therefore in this case in a concentration of approximately 1 in 300,000 to 1 in 500,000.

In another experiment a Jonathan apple was exposed to the AsH_3 from 5 mgms. of As_2O_3 for one week. After three weeks in air, the skin was browned all over, and a few shallow pits developed. Even here the Federal Analyst was able to detect distinct indications of the presence of arsenic, although apparently hardly in accurately measurable quantity.

Perhaps the most important point here is that apples appear to have the power of decomposing arseniuretted hydrogen and retaining its arsenic. The gas itself is only sparingly soluble in water, and after two to three weeks in air, it is hardly likely that any of the gas could still be present as such in the apples particularly when the arsenic is only present in the skin, as in the first and last experiments. Hence very minute traces of arseniuretted hydrogen could be picked up and accumulated by apples until in time the exceedingly small amount necessary to poison the pulp cells was reached, which would in this case be at points under or near to the breathing pores or to the centre of the fruit.

PART II.

THE PROBLEM OF BITTER PIT.

According to C. P. Lounsbury (Agricultural Journal, Cape of Good Hope, 1910, page 150), this disease is a physiological one. The spots develop while the apples are on the trees, and also in apparently healthy fruit after storage. Certain varieties are more immune, particularly those from colonial seedlings. Hence he considers that by the selection of resistant varieties, the disease may be partly controlled.

I. B. P. Evans (Transvaal Department of Agriculture, Technical Bulletin I.) found that all imported varieties were more or less subject to this disease, but that two native seedlings were practically immune. The spots arise in close connection with the vascular bundles where the excess pressure bursts the pulp cells. The oxygen with the enzymes acts on the tannin, producing dark coloured oxy-compounds, and drastic action is inhibited. The bursting pressure is produced during the night stoppage of transpiration.

Cases of cells bursting during development are known to occur with pollen tubes and root hairs, but only when grown under abnormal artificial conditions, and here we are dealing with unicellular structures. Pole-Evans has overlooked the fact that in the pulp cells of the apple we have a tissue in which the cell walls press against each other, and hence are under compression instead of tension at the points of contact. Further, a localised increase of pressure by distending the walls would diminish or obliterate the air spaces, and bursting would only occur when the breaking strain was reached before the expansion was completed. In plant tissues this appears only to occur when preceded by a softening of the cell wall, of which there is no sign in bitter pit.

Further, puncturing young apples and half-grown apples on the tree with fine sterilised needles so as to rupture some of the pulp cells, may result in the production of flat or crater-shaped more or less corky superficial scars, but never causes an appearance of bitter pit in Jonathans, Five Crowns or Scarlet Nonpareils.

Pole-Evans' theory is apparently based upon the idea that the stoppage of transpiration produces a sudden increase of pressure, just as occurs when a stream of water flowing through a hose pipe is blocked at the orifice. This is of course a fundamental misconception, since the osmotic pressure depends upon the osmotic concentration of the cell sap which the plant is able to control, and as soon as the hydrostatic pressure in the cell balances the osmotic pressure, further absorption of water ceases.

Pole-Evans' theory was based upon the simple observation, which is quite correct, that sections of bitter pit tissue commonly show broken cell walls. The same is also shown in artificial bitter pit tissue produced by poisoning. As the cells die and shrivel, the walls become brittle, and being thin are easily broken either by the general contraction or by the tearing of the razor during the section cutting. Natural bitter pits treated with dilute potash and carefully teased out may sometimes not show a single broken cell-wall, and the more carefully sections are cut the fewer are the broken cell walls. Further, when broken cell walls appear naturally in artificial bitter pits, they usually occur at the boundary of the pit tissue and normal pulp cells, the adherence of the former to the skin causing the breaks when the shrivelling is pronounced. In both natural and artificial bitter pits, any breaking of the cell walls follows instead of precedes the formation of the pit.

Dr. White then investigated the enzymes of apples affected by bitter pit, and from her observations, came to the conclusion that the non-solution of the starch grains which usually accompanies bitter pit could only be explained as a symptom of local poisoning. She was able to detect the presence of lead in the bitter pit tissue of apples from an orchard which had been heavily sprayed with arsenate of lead[1]. The fact that bitter pit may also occur in orchards which have never been sprayed does not affect the theory that bitter pit is not a disease at all, but a symptom of local poisoning. The two most trenchant criticisms made to contest the statement that bitter pit could ever be due to poisonous spraying materials were—(a), that if so, it would occur most in the cup at the stalk end of the fruit, and (b), that in the apples examined by Dr. White the lead might have entered after the bitter pits were formed. In regard to (a) the answer is simple. The stalk end is at first convex, and the cup only develops as the fruit becomes adult. It is then almost without exception covered by a more or less corky, protective, impermeable layer, and has few or no breathing pores through which poisons could enter. The reply to (b) is given by the experiments already detailed and to follow.

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[1] Proc. Roy. Soc. of Victoria, 1911, p.1.

The fact that poisonous sprays may affect the foliage is well known, and it would be in the highest degree remarkable if under no circumstances were any effects exercised on the fruits. In 1902 Bain investigated the injurious action of copper fungicides on peach foliage[1]. He found that penetration did not necessarily take place through the stomata, and that the injury might appear at some distance from the point where the drop of spray material (Bordeaux mixture) was applied. Further, he found that at first the production of starch was increased, and that later signs of injury or death were shown. If the amount of poison is sufficient, the dead cells will retain undissolved starch grains. In other words, we have here a "bitter pit" of foliage directly produced by poisonous sprays. Bain also found that seedling apples were more sensitive to poisons than seedling peaches, and were rapidly killed when a solution containing 0.0000075 gram molecules of copper sulphate per litre was applied to their roots.

G. Stone (Massachusetts' Station Report), found that during 1909 spraying with Bordeaux mixture caused noticeable injury to apple foliage and fruit, and that arsenate of lead spraying caused foliage burning, especially on plum trees, but also on maple and beech.

W. N. Scott (Phytopathology, 1911, page 32) found that a fruit spot of apples, particularly of Jonathan and Esopus, which develops usually after picking, is dark brown, usually circular, from $\frac{1}{4}$ to $\frac{1}{8}$ inch or less in diameter, and slightly sunken with a lenticel in the centre of each spot. It has been observed in apples from Iowa, Missouri, Virginia, New York, Oregon and Washington. The cause is uncertain, but it is suspected to be due to injury by arsenate of lead used in spraying. Low temperatures retard or prevent its development.

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[1] Agric. Exper. Station, Univ. of Tennessee, vol. xv., p. 21.

P. O'Gara ("Better Fruit," 1911, p. 28) writes "On the spotting of apples by arsenate of lead." The spots are confined to the epidermal and sub-epidermal cells. An unsprayed orchard with neglected trees did not develop a single spotted fruit except where the trees were sprayed with a soluble arsenical poison. The greatest amount of injury was found in trees in the very best condition, growing prize fruit and regularly treated. Analyses of 10 gramme samples of the epidermal and sub-epidermal tissues showed that the black and red spots contained from 0.03 to 0.05 milligramme, while the apparently sound skins showed 0.025 milligramme of arsenic. One analysis of very badly spotted apples showed a quantity of arsenic equal to 0.3 mg. of As_2O_5(0.005 grain). There is no danger from eating such apples, as at least 5 milligrammes are required to produce a marked effect. The author advises the use of at least one pound of unslaked lime with each pound of lead arsenate.

In view of the foregoing results direct tests were made with various spraying materials.

Arsenate of Lead.—That this and other spraying materials termed "insoluble" are not absolutely so was shown by the fact that a clear saturated solution from Sherwin-Williams' new process arsenate of lead contained 0.06 of dissolved solids.

Jonathan apples rubbed with the solid, then wiped clean and wetted daily with water, developed numerous black spots at the lenticels, but even after eight weeks none exceeded 1 to 2 mm. diameter and 0.5 mm. depth, and the pits were no larger even when minute punctures not exceeding 0.2 mm. diameter were made in the skin prior to rubbing with arsenate of lead. If fragments of the cuticle 1 mm. square were removed, dark, circular brown pits formed, increasing to 2 to 4 mm. diameter and 1 to 3 mm. deep in eight weeks. Prepared apples placed for one week in a clear filtered solution from 5 grams of arsenate of lead in 1 litre of water, filtered after standing, showed in three weeks well-developed pits 1-2 mm. deep beneath each prepared spot. With a similar solution from Paris Green the pits were 3-4 mm. deep, but with solutions from lead chromate and London Purple, only a superficial browning and a few pits not exceeding 1 mm. depth were formed.

Sound apples with a normal skin floated for one week on clear saturated solutions from arsenate of lead, lead chromate, London Purple and Paris Green, allowed to stand, decanted, and then filtered, showed after three weeks in air from a few to numerous small superficial spots, but no pits, and the pulp was wholly sound. The above tests were done with Jonathan, Yates' Pippin and Scarlet Nonpareil apples.

Evidently, therefore, all these substances are sufficiently poisonous to poison the pulp cells when they gain entry, but are unable (in solution in appreciable amount) to directly penetrate the skin of a sound adult apple with a well-developed cuticle and bloom.

Bain (l.c. p. 43) found that the injurious action of Bordeaux mixture and copper hydrate on peach leaves was greatly decreased in the presence of free lime or calcium carbonate. Hence, the influence of these substances by themselves was tried. Apples floated on lime water had chalk deposited on the skin, but even after one week showed no signs of injury, and the chalk readily rubbed off.

Prepared apples placed in saturated lime water for one week formed shallow brown pits beneath each prepared spot on keeping, in a 1-10th saturated solution only a superficial browning appeared, and a 1-100th saturated solution produced no perceptible effect. Prepared apples placed in a clear saturated solution of lead arsenate, to which an equal bulk of 1-100th saturated lime water was added, showed no signs of poisoning, or only very faint superficial browning even after one week.

It is quite clear therefore that the addition of free lime to arsenate of lead diminishes its toxicity, and would probably also make the same quantity go further in practice. Whether the mixture would be equally effective and firmly adherent could only be determined by field trials.

Other spraying materials.

Apples rubbed on one side with emulsified spraying oil (Emulsi-A-01), developed in one to three weeks several circular pits 1-3 mm. diameter and depth beneath some of the lenticels, and a few larger irregular, superficial, brown, discoloured patches on this side, but not on the other. When rubbed with red oil, no effect was produced. Apples are not sensitive to all poisons, antiseptics or disinfectants. Thus when rubbed strongly with iodoform, and then wiped clean, a faint smell of iodoform was perceptible, even after three weeks. A few of the lenticels showed as small superficial brown spots, but no pits were developed, and the pulp remained sound throughout.

Can surface poisoning produce deep seated bitter pit tissue?

In all the experiments on adult apples with liquid or solid poisons, the effects were always produced first at the point where the poison was applied, and thence radiated inwards, but in normal bitter pit, the dead tissue may sometimes be deap-seated without any apparent connection with the exterior. There is, however, a possibility that poisons might enter in too small amount to poison the resistant young apple cells, and later when more deep-seated, might poison the adult pulp cells as soon as their resistance had decreased sufficiently.

As a matter of fact apples appear to grow more peripherally than centrally after setting. Thus in Jonathan and Five Crown apples of 1 and 1.1 cm. radius, the diameter of the central core was 0.4 cm., giving ratios of 2.5 and 2.75, whereas in adult apples the relationships were:—

Radius of apple.	Radius of core of loculi.	Ratio.
3	0.8	3.75
3.7	1.2	3.03

Hence poison originally near the surface might become deep seated as the apple grew to adult size, in just the same way that substances at first on the surface may in time be imbedded deeply in growing wood. In the case of the apple, however, we should expect to find in most cases at least, a more or less prominent track up to the surface, and probably many or most of those cases where so such track is perceptible, and where the bitter pit tissue is entirely deep seated, are the result of the absorption of minute traces of poisons through the roots, or less probably, of volatile substances from the air.

To determine this, young apples three weeks old, as yet with no starch, were finely punctured just through the skin, and rubbed over with arsenate of lead. At three months all those remaining on the tree showed deep brown spots at or below the point of injury, and in some cases it was difficult to trace any connection with the injury on the skin. The dead tissue in this case contained few starch grains as compared with the normal pulp, but this was because most of the cells were killed before the deposition of starch grains had begun in the pulp tissue.

The starch grains of bitter pit.

One of the characteristic features of bitter pit is stated to be that cells filled with starch grains occur in the dead tissue when none are present in the healthy pulp cells. Out of some hundreds of artificial bitter pits examined which had been produced by different poisons, practically in every case where the pits were sufficiently large, occasional isolated cells packed with starch grains could be detected. At first this appeared to point to a condensation of starch in the cells as they were gradually killed by minute traces of poison. Prepared adult apples floated on dilute non-poisonous solutions of glycerine, sugar and formaldehyde, showed no perceptible formation and accumulation of starch in the pulp cells under the prepared spots, so that apparently the leucoplastids in adult pulp cells, which still appear to be present in some cases particularly near the surface, appear to have lost the power of producing starch. Further investigation showed that the presence of occasional cells, or even groups of cells living but packed with starch grains, is a common and almost universal occurrence in ripe apples. The sound pulp of more than 200 ripe apples of the kinds mentioned above was examined for starch, and in 95 per cent. with positive results. These starch cells are always sparsely scattered in sound apples, and are least abundant in Five Crowns and most in Jonathans. The individual starch cells when present are, however, packed with starch grains showing no signs of solution. In Five Crowns there are rarely more than 0 to 6 such cells in a preparation 1 cm. diameter, and 1 to three cells thick, whereas in Jonathans there may be from 0 to 50 such cells present in the same amount of sound, living pulp. These cells show no other signs of injury or death, their protoplasm appeared to be living, and when tested on carefully made preparations was plasmolysable. A sound, ripe Jonathan apple, free of all external signs of bitter pit, may, therefore, contain some thousands of living but starch-bearing cells. So far as the apples examined were concerned, the non-solution of the starch grains in occasional scattered pulp cells is not an abnormal but a normal phenomenon.

The non-solution of the starch grains.

The question at once arises, Why do the starch grains in occasional cells of otherwise sound apples and in numerous cells in ordinary bitter pit tissue, remain undissolved during ripening?

In the first place it must be noted that natural bitter pit is not accompanied by cells with undissolved starch grains if it appears or is produced in young apples before the starch grains have appeared in the general pulp. Such apples usually fall off without ripening, probably as the result of excessive poisoning[1]. Secondly, when it develops late after storage, there may be no more starch grains in the dead tissue than in the general pulp. Thus Jonathan, Sturmer Pippin and Scarlet Nonpareil apples, which had been heavily sprayed during development, were picked over, and all bitter pit apples removed. An abundance of starch grains was present in the bitter pit tissue in every case. The sound apples were kept in cool storage for four months. Many of them developed large, deep bitter pits, almost every one of which was beneath a breathing pore. Occasional starch containing cells were present in the dead tissue, but not perceptibly more than in the healthy pulp tissue.

The non-solution of starch grains in living pulp cells can only be due to the following factors:—(1) the diastase ferment which converts the starch into sugar during ripening is not developed; (2) the cell contains an excess of the product of the diastase reaction, sugar; (3) the starch grains are composed of some special insoluble form of starch; or (4) some poison is present in sufficient amount to inhibit the action of the ferment, without necessarily killing the cells until their power of toxic resistance has fallen to a sufficiently low ebb.

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[1] This may be the reason for the fact that so many young fertilized apples often fall from apple trees for no apparent adequate reason.

Living pulp cells with undissolved starch grains were soaked in Fehling's solution for half-an-hour, and warmed. Doubtful or no traces of reducing sugar could be detected in them. The same negative result was given after previous warming with dilute sulphuric acid. If they contain any sugar at all, they contain less than ordinary pulp cells. Further, they do not appear to be either constantly more or less plasmolysable than ordinary pulp cells. Possibly they contain some substance in solution which makes up for the absence of sugar[1]. Indeed, if this were not so they would be crushed and flattened during development by the surrounding cells, whereas in adult apples these living starch-bearing cells, though frequently smaller, are often quite as big as the ordinary pulp cells. In any case the non-solution of the starch grains is not due to the cells affected containing an excess of sugar.

In regard to the diastase ferment the following experiment was performed. Two adult prepared Jonathan apples in which small bitter pits had been produced by 1 per 500,000 and 1 per 2,500,000 solutions of lead nitrate, and two ripe normal apples were kept in all for 10 weeks in air at room temperature. Occasional cells with uncorroded starch grains were still present in the sound pulp of all four, and in the dead pit tissue of two of them. The peel and dead pit tissue was then removed, and the pounded pulp of each extracted for diastase[2]. The filtered precipitate from each was divided into two parts, to each of which starch solution was added, and one, the control, was immediately boiled. Both were then kept warm for some hours, and then tested for reducing sugar.

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[1] This may lead to a vicious cycle. Thus the presence of an infinitesimal trace of poison may delay the solution of starch and cause the cell to contain less sugar than its neighbour. It may maintain its osmotic pressure by absorbing salts from them. If these are at all poisonous, the poisoning becomes more severe and may lead to death, some cells being thus sacrificed as poison traps to preserve the rest.

[2] These tests were performed by Dr. White.

	Weight of pulp.	Reduction of Fehling's.
1. Normal apple	66 grams	Slight
2. Pitted apple	65 grams	Slight
3. Pitted apple	59 grams	Very faint
4. Normal apple	74 grams	Very faint

Distinct traces of diastase were present in all four cases, and although the amount is small, it is impossible that the starch grains could have remained for 10 weeks without any signs of corrosion, unless something was present which inhibited the diastatic action. Nor is it possible that diastase was present only in the pulp cells without starch grains, for it is well known that diastase can diffuse from cell to cell[1], and the starch-bearing cells were scattered throughout the pulp tissue.

That there is nothing peculiar in the undissolved starch grains found in normal apparently healthy apples was found by microchemical examination, with the aid of iodine, potash, heat and polarised light. Nevertheless it was not found possible to dissolve them by the aid of solutions of commercial diastase, freshly-prepared barley diastase or "ptyalin," even after applying fresh diastase solutions daily for a week. Thin slices of the pulp were then washed repeatedly with dilute ammonia, dilute hydrochloric acid and water. The starch grains in the starch cells dissolved partly or entirely after three to seven days in freshly-prepared barley diastase, but even then some cells could still be found with starch grains apparently entirely unaffected. If bacteria or fungi were allowed to develop freely, all the starch grains were dissolved in 3 to 14 days, and by the latter time the pulp cells separate from each other, but may remain with unbroken walls for a very long time in the absence of cellulose bacteria. The starch grains may dissolve before fungal hyphae reach them, and form at first an irregular amorphous faintly blue-staining mass, or a granular débris in the cells which originally contained clusters of well-defined starch grains.

Similar results were obtained with natural bitter pit tissue containing abundant starch cells, but here is some cases even after long washing with acid, alkali and water, and in the presence of bacteria and fungi, starch cells could still be found after three weeks quite unaffected and undissolved. Apparently the poison inhibiting diastatic action in such cases is a metallic one, firmly adhering to the starch grains. Actual tests showed that the addition of one gram of arsenate of lead to 1000 grams of starch completely protects the starch grains from the corrosive action of ferments, if a thorough mixture is made prior to adding the solution of the ferment, and this although arsenate of lead is a comparatively insoluble poison.

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[1] When fungi are grown on apples containing starch, the grains may begin to dissolve while still an appreciable distance from any fungal hyphae, particularly at any point where the growth of the latter is retarded.

Apples affected with natural bitter pit were inoculated with the hyphae of *Penicillium*, and other undetermined saprophytic fungi, taken from apples undergoing soft rot. The hyphae grew freely in the sound pulp, but usually distinctly avoided the bitter pit areas, at first growing right past or around them before invading them laterally. The starch grains in the bitter pit areas remain partially undissolved long after any starch grains which may be present in healthy pulp cells have disappeared. Obviously the bitter pit areas contain a higher percentage of poison, and the fact that the hyphae will ultimately grown into them is not surprising, since they also grow freely in apples poisoned throughout by mercuric chloride or copper sulphate. Similar results were obtained with artificial bitter pits produced by 1 per 100,000 concentrations of mercury and lead, and to a less extent by copper.

If the poison in question were not the originating cause of the bitter pit, but were produced by the secondary changes during the development of the pit evidenced by the change of colour, by the modification of the cell wall and by the disorganisation of the protoplasmic cell contents, then it should always be repellent to saprophytic fungal hyphae. Artificial bitter pits produced by minimal toxic concentrations of metallic poisons are penetrated by fungal hyphae as readily as, or even more readily than, the healthy pulp tissue or natural pit tissue, and the pits produced by formaldehyde ammonia, potassium and magnesium in moderately toxic concentration, exercise a distinct attraction upon the fungal hyphae. Evidently, therefore, the secondary changes during the development of bitter pit do not result in any noticeable production of distinctly toxic materials. In other words, any poisons present in the pit tissue are the cause of the pit and not the result of it.

The source of the poisons causing bitter pit.

None of the volatile poisons tested appear to be likely causes of bitter pit under natural conditions, and their action would not suffice to explain the permanent character of the poisoning and its localised origin. Nor do apples appear to have any power of autotoxication sufficient to explain the symptoms observed, although they do produce, when young, traces of formaldehyde, which is a poison in excess, but only a relatively feeble one. Its action would, however, be a generalised and a rapidly spreading one, and the tests quoted above showed that it was from 3000 to 300,000 times less poisonous to apples than copper and mercury salts, and, in fact, less poisonous to apples than any of the other poisons tested, with the exception of ammonia and lime water. Evidently, therefore, the poison must be derived from outside the plant, either (1) directly through spray poisons applied to the surface, or (2) by poisons absorbed from the soil through the roots.

The bitter pits starting from the surface usually beneath lenticels are largely due to the entry of spray poisons. If the development takes place late, when the apples are adult, the pit tissue will contain no starch grains, and the same is the case when pits are formed in very young apples. The action of the poison is not to cause the condensation of starch grains, but their non-solution during ripening. Nearly every apple, even if apparently sound, has a few cells in which the requisite toxic concentration has been reached to do this. Such cells only die when either the concentration increases as the result of the continued flow of sap and the evaporation of the surplus water, or when the resistance of the cells with increasing age falls to the toxic limit. This incipient bitter pit which appears to be almost always present in apples, is certainly the result of the absorption of poisons from the soil, and certain food elements (Ca, Mg, K) are capable of acting as poisons when they are not present in their appropriate relative concentrations. The complete and permanent localised arrest of ferment action can only, however, be due to the presence of minute traces of an extremely poisonous heavy metal, such as lead, mercury, copper, etc., or even of gold[1], barium or arsenic compounds.

Poisons derived from the soil may be naturally present, or accumulated from the continued use of poisonous sprays, or from the use of poisons to destroy weeds. Half-a-pound per acre represents a concentration of more than 1 per 100,000,000 per acre of soil one foot deep, and this is the limit of toxicity of copper sulphate to the pulp cells of some varieties of apples. A single Bordeaux spraying may consume more than six lbs. of copper sulphate per acre, most of which ultimately finds its way to the soil. In the case of arsenate of lead, some growers spray 3 to 10 times per season, which represents a considerable addition of poison to the soil, and is furthermore repeated annually. Fortunately plants never absorb more than a small fraction of the total amount of any one substance present in the soil, and although good humus soils are very retentive to metallic poisons, there must be a certain annual removal of poison by drainage. It would, however, be interesting to know whether copper, lead or arsenic can be detected in the soils of long sprayed orchards in amounts approaching or exceeding the limits of their toxicity to the pulp cells of apples.

In order to explain the fact that bitter pit is so much more abundant in well-tended and well-sprayed orchards than in neglected, untended ones, many orchardists have suggested that the ploughing may make the roots grow deeper than normal, and so cause interferences with nutrition. This may be the case if the subsoil contains minute traces of poisons, but otherwise it is not a likely explanation. In the same way the disease has been referred to the use of particular stocks or grafts. The nature of the stock or scion may affect the tendency to a particular disease, just as some organisms are resistant to particular poisons or contagious diseases, but this affords no explanation of the cause of the disease in question. In the same way, the fact that cancer seems sometimes to run in families may show that the tendency of the disease may be to some extent hereditary, but gives no explanation or cure for the disease itself. From the purely practical point of view the discovery of a completely resistant stock is highly improbable, and resistant varieties of cultivated plants very frequently have the unfortunate peculiarity that they are economically unprofitable.

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[1] Gold is so readily precipitated in contact with organic matter that the possibility of its absorption from soils seems somewhat remote.

SUMMARY.

The ripe pulp cells of apples are more sensitive to various poisons than any other known organisms, the limit of toxic action in the case of mercuric chloride being with a concentration of 1 in 10,000,000,000. The sensitivity to poisons varies considerably in different varieties, and the pulp cells on the shaded side of an apple are more sensitive to poisons than on that grown exposed fully to the sun.

The cuticle and bloom of sound apples are remarkably impermeable to poisonous solutions. Moderately dilute solutions of metallic poisons penetrate through the breathing pores in sufficient amount to produce bitter pits, and yet in such minute quantities as to be incapable of detection, even by very delicate chemical analysis.

When the cuticle or bloom is removed penetration takes place readily. Hence apples should never be wiped or polished until just before they are eaten. Apples have a certain power of accumulating mercury and similar poisons from extremely dilute solutions, but nevertheless, mercuric chloride is poisonous to the pulp cells of apples without any accumulation in concentrations down to 1 per 100,000,000, and possibly even lower. Copper is not quite so poisonous as mercury, and lead much less so, while its action is also slower.

Young apples are more easily penetrated by dissolved poisons than old ones, but their pulp cells are much more resistant. Hence a young apple may absorb sufficient poison to kill a portion of its tissue when adult, without any immediate toxic effect being shown.

Food and other substances occurring normally in the soil may exercise a toxic action when presented singly, but in mixtures their individual poisonous action is decreased.

The poisonous action of copper sulphate and other soluble metallic poisons to apples, may be decreased by the addition of substances which decrease the percentage of free ions, and on these lines it may be possible to modify even such relatively insoluble spray poisons as Bordeaux mixture and arsenate of lead, without appreciably affecting their value as insecticides and fungicides. Zinc arsenite has been recently suggested as being equally effective as an insect poison, and less poisonous to plants than lead arsenate.

Nevertheless since the fungus, *Penicillium*, which is a common cause of wet rot in apples is able to grow on a 20 per cent. solution of copper sulphate, it is 2,000,000,000 times more resistant to copper than the pulp cells of apples, and it is also very much more resistant to mercury salts[1]. In this case "fungicides" will kill apples long before they kill the fungus. Of gases present in the air, ozone, ammonia and nitric acid are able to produce surface pitting in apples, but only in amounts and with lengths of exposure relatively much greater than those presented under ordinary conditions.

Five milligrams of solid iodine placed a foot distant from an apple can cause it to become covered with spots and pits in the course of time.

Apples absorb and accumulate arsenic from arseniuretted hydrogen, a strong poisonous action being exercised when a concentration of 1 of arsenic trioxide per 500,000 of apple pulp is reached. When once within the pulp cells, lead arsenate is poisonous in a concentration of 1 in 13,000,000.

The following results conclusively show that the "disease" of apples known as bitter pit is, strictly speaking, not a "disease" at all, but is a symptom of local poisoning.

Bitter pit symptoms, including the presence of abundant starch grains in dead cells, are frequently shown in the spots appearing on peach and apple foliage, when burning is produced by poisonous sprays. Not only arsenate of lead, but all the other common spray poisons are effective causes of bitter pit in apples. When the entry takes place from the surface of the apple at the close of ripening, the pits are superficial and without starch grains. The usual characteristics of bitter pit are only shown when a toxic concentration is reached after the cells have become packed with starch. This at first prevents ferment action, and later kills the pulp cells.

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[1] *Penicillium* can also withstand 15 per cent. of zinc sulphate, 37 per cent. of manganese sulphate, 8 per cent. of ferric sulphate and is also resistant to arsenic, all of which are poisonous to ordinary plants.

The first stage of bitter pit, namely, the presence of occasional cells with starch grains which do not dissolve during ripening in perfectly sound ripe apples, is apparently almost a normal phenomenon whether the apples are from sprayed or unsprayed orchards. This is the result of their extraordinary sensitiveness to traces of poisons.

In such apples and in bitter pit apples from unsprayed orchards the poison must be absorbed from the soil. The relative incidence of bitter pit in sprayed and unsprayed orchards is a matter of great importance. If 90 per cent. occur in sprayed and 10 or less in unsprayed orchards, the immediate problem is to find a substance which will diminish the toxicity of spray poisons to plants, while leaving them equally effective against the insect pests which eat and digest the poisonous spray with the plant tissues.

Among such substances appear to be lime and citric acid, but much more effective ones may be found. So far as the evidence goes at present, bitter pit appears to be much more prevalent in sprayed orchards than in ones which have never been sprayed or had any poison applied to the soil.

On the other hand if only a minority of cases of bitter pit are directly or indirectly due to the use of poisonous sprays, it will be necessary to find what poisons are absorbed from the soil or subsoil, and what correctives can be applied to them. This is a chemical problem of some difficulty, since the traces of poison required to produce bitter pit symptoms in the pulp cells of apples are almost infinitesimally small, and a number of different poisons may be acting on different trees in the same orchard.

On three points, however, it may, I think, be stated with confidence that we are on a solid bed rock of established fact, namely, that bitter pit is, strictly speaking, not a disease at all, but is a symptom of local poisoning produced in the sensitive pulp cells of the apples, that more than one poison may produce it, and that such poisons may be derived from more than one source.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXVII.—*Machine-Drawn versus Hand-Drawn Milk: An Enquiry into the Relative Bacterial Content.*

By NORMAN MacDONALD, B.V.Sc.

(Government Research Scholar in the University of Melbourne).

[Read 14th December, 1911.]

In Australia perhaps even more than most other parts of the world, the provision of some mechanical means whereby the drudgery of milking cows by hand can be at least reduced to a minimum, if not entirely obviated, is by many considered a necessity if the dairying industry is to develop to its full extent.

Year by year dairymen are finding it more difficult to secure the necessary labour for the milking of cows, chiefly because it is work that permits of few or no holidays, and because it is work that, although not onerous, is very exacting.

It is many years since the first mechanical apparatus was devised for milking of cows, but it is only within the past decade that any of these has proved even a comparative success. That such milking machines are growing in favour year by year is evident to anyone who cares to keep in touch with dairying interests, but in the opinion of many the use of such machines is deleterious to the cow's udder, and to the purity of the milk supply. On the other hand it is held by many intelligent farmers who have had experience of the machines that the modern forms of the apparatus more closely simulate the action of the calf's mouth and tongue than does the human hand, and that provided the machine is properly attended to, especially as regards cleanliness, the mammary gland is not affected, and the possibility of bacterial contamination of the milk is greatly minimised.

In view of these opposing contentions, both of which are to be found supported by very definite statements, and in the absence of comparative records of the two processes being carried out under satisfactory and uniform conditions, it seemed highly advisable, especially as it is obvious that a satisfactory machine would prove of great value to the industry, that some scientific investigation should be made.

The opportunity for such an investigation presented itself last summer. The Lady Talbot Milk Institute, a charitable organisation instituted for the special purpose of providing infants with a pure milk supply from healthy, tuberculin tested cows, has for the past two or three years secured its milk from a farm where the milking is accomplished by the use of the milking machine. This Institute expressed its desire to have a comparative test of both methods made, the test to continue for the summer months, and offered every facility for carrying out the tests. The farm being under the constant supervision and immediate control of a Government dairy supervisor the circumstances were such as to render possible a complete comparative test of the two methods, the old and the new, working side by side, and under the very best conditions practicable.

Farm and Herd.

The following extracts from the report of the supervisor, Mr. McAdam, as presented to the Institute, furnish a full account of the milking herd and the management thereof:—

"The number of cows milked daily throughout the season averaged 95, chiefly of the Ayrshire type, all having undergone veterinary inspection and the tuberculin test at various times since 20th December, 1910. They were kept in good condition, well fed and groomed twice daily, stalled at nights, and during the day turned out into an area of about 20 acres, leased in connection with the farm as a run and exercise ground for the cows. The cows were brought up into the bails clean, and in a condition satisfactory for the supply of pure milk of the standard required by the Board of Management for the Institute."

Food Supply.

"The cows were fed mainly on fodder crops grown on the farm, with the addition of bran and a limited quantity of brewer's grains, any food likely to be detrimental to the milk supply being guarded against, and no feeding allowed in the milking shed, but given to the cows immediately after milking."

Milking Methods.

"The milking has been done throughout the season with three L.K.G. milking machines. Before the machines were applied the milk of each cow was carefully examined by the supervisor, a small quantity being drawn from each teat for the purpose, as a check against milk being used from injured udders, and also as a means of detecting the symptoms of any of the various diseases of the udder affecting the milk supply. These precautions were taken daily throughout the season. The foremilk, about four streams from each teat, was then taken, and the teats and udders were carefully washed with warm water, clean water being used for each pair of cows. The machines were then applied, and after removal the cows were stripped out by hand into special buckets with cotton-wool strainers fitted into the mouth. The milk, after being weighed, was passed through a cleansing centrifuge, and thence over the refrigerator, and the temperature reduced to 40 deg. Fahr., and immediately bottled, sealed and dated, placed in crates, packed in ice, and delivered to the distributing agents within four hours after being milked, every precaution being taken during the whole process to ensure cleanliness. All utensils, milk bottles, and everything coming in contact with the milk was sterilised twice daily. All teat cups and rubberware in connection with the milking machines were boiled twice daily in soda water 10 per cent. strength, and left in the sterile water between milkings, and immediately before being used were blown out with dry steam. The machines were also sterilised at intervals during the milking operations by being placed in boiling water and soda after each machine had milked a pair of cows, opportunity being taken for this work in the interval during which the bails were hosed down and a fresh section of the herd brought in. The process of sterilising the milking machines received special attention by the supervisor through the season. All the employees at the dairy were provided with a clean suit of overalls and cap for each milking, and received instructions from the supervisor throughout the season on sanitary methods in the production and handling of milk for infants, the same staff being employed right throughout the season."

Possible Sources of Bacterial Contamination.

Before describing in detail the results of the investigation it may be well to consider this subject.

It is well known that from many cows, provided that stringent precautions are taken, small quantities of absolutely sterile milk can be secured. Such extravagant precautions are, however, impossible in ordinary hand-milking conducted as a commercial undertaking. All that can be done is to minimise as far as possible the known sources of contamination. That much may be achieved in this direction is proved by the results not only of the examination of milk from the special cows reserved for this comparative test, but also by the results obtained by Dr. Bull in his examination of the general milk supply of the Lady Talbot Milk Institute. (See Report for 1911, p. 15.)

In hand-drawn milk the chief sources of contamination are:—

1. The milker's hands, and to some extent, his garments. In many cases there is no doubt that such are very important factors, especially where the method known as wet-milking is pursued.
2. The skin of the cow, particularly that covering the udder and teats. This is a common source of infection, for often no precautions are taken in regard to thorough washing of the udder and grooming of the flank, consequently scurf, etc., frequently enter the pail.
3. Atmospheric dust and manure particles falling into the bucket during and subsequent to the process of milking.
4. The milk in the teat duct. It is well known that the first milk invariably shows a much larger bacterial content than the average milk, due to invasion by

bacteria through the orifice of the teat duct between milkings.

In regard to the machine the chief sources of contamination are likely to be:—

1. The surface of the teat, which is being intermittently washed by the milk as withdrawn.
2. Air drawn into the cup at each pulsation through the small "air admission" aperture.
3. Bacteria within the teat duct.
4. Dirt within the apparatus itself.

It would seem therefore that the possible sources of infection are greater for the hand-drawn than for the machine-drawn milk, for the latter is but little exposed to contamination by the milker's hands, by the skin of the cow, or by dust and manure particles, as the receptacle is covered during the whole process of milking.

On the other hand if the mechanical apparatus be not thoroughly cleansed after use and small quantities of milk be allowed to remain in different parts between the times of milking, a suitable medium for the rapid multiplication of bacteria is provided, and a fertile source of danger is bound to be established.

In the investigation under review an endeavour was made to eliminate as far as practicable each and all of these sources of contamination in both the hand and the machine milking. For example, cleanliness in regard to the milker's hands and garments was insisted upon; washing the cow's udder and teats, and grooming the flanks with a damp brush was practised. The first ounce or two of the fore milk was withdrawn by hand and discarded, and in the case of the machine the apparatus was thoroughly sterilised, as can be seen by the supervisor's report already quoted; while the premises were kept in a thorough state of cleanliness.

For the purpose of the comparative test, four cows were selected, all being approximately of the same age, breed and condition, and each giving about the same quantity of milk. Two were carefully milked by hand and two by machine. Fair samples from the total supply of each pair were placed by Mr. McAdam, the supervisor, in sterile bottles, securely stoppered and immediately cooled to about 40 deg. Fahr. These bottles, each containing a pint, were retained at a low temperature until delivery at the laboratory, where they were placed in an ice chest until tested.

The tests were conducted during January, February, March and April. During April, owing probably to the cooler weather, a marked general decrease in the bacterial content of both milks was experienced, the total number in each often falling below 250 per c.c. For this reason, the counts obtained in April have not been included in working out the averages given below.

On several occasions samples were delayed through various circumstances, so that they did not arrive at the laboratory until the second day after milking, and on other occasions, through error on the part of the agent, both samples were not received simultaneously, consequently certain days' records could not be included; but this does not interfere with the general results.

Throughout the test the appearance and palatableness of both milks were excellent, no taint or odour ever being detected, and the bottles on standing showed a good layer of cream. In regard to ordinary keeping qualities the milk, when kept in the ice chest at about 50 deg. Fahr., invariably remained perfectly sweet and wholesome for at least 48 hours after milking, even during the hottest summer months.

So far as the health of the cows, the condition of the udder and the quality of the milk, were concerned, throughout the whole period no difference whatever could be detected between those milked by hand and those milked by machine.

General Bacteriological Results.

Throughout the period under review the average number of bacteria present per cubic centimetre was in the hand-milk 7500, and in the machine-milk 6750. Naturally there was often a decided difference between the bacterial content of the two samples. For example, it was found that on 25 occasions the hand milk contained at least twice the number of bacteria present in the machine milk, while on 12 days the machine showed at least double the number found in the hand milk.

For the first six weeks the strippings of the two machine-milked cows were added to the bulk before the sample for examination was secured. Subsequently, however, this practice was discontinued, it being considered that such a method was really not fair either to the hand or the machine, as of course the strippings were removed by hand.

That the removal of the strippings by hand and their subsequent addition to the machine milk seemed to deteriorate the latter from the standpoint of bacterial purity is indicated by the following figures. During the period when this practice was adopted the hand milk showed 5000 bacteria per cubic centimetre, and the machine milk showed 10,750 bacteria as daily average, but during the following period when no strippings were added to the machine-drawn milk the average figures were 9500 for the hand, and but 3500 for the machine.

It must not be understood, however, that any definite and absolute conclusion can be drawn from these figures, for as a matter of fact, it will be seen that during the first half of the first period, the average tests were much more approximate than during the second half.

Bacteria Isolated.

For the first few weeks the nature of the different bacteria found present in the plates was carefully ascertained by subcultures on different media.

It was found that both the species and the relative number of each species varied so greatly that any results of scientific value could not be expected from pursuing this work further. In regard thereto, it is sufficient to state that in addition to the ordinary bacteria inducing lactic acid fermentation, *cocci* (particularly *staphylococci*) and *sarcinae* were common, while the *streptococcus* was conparatively rare. Various forms of saccharomyces were frequently encountered. The *colon* bacillus was not common, and the liquefying bacilli present were those found commonly in water.

A number of doubtful organisms were tested as to their pathogenicity for laboratory animals, but in no instance were the results fatal, and rarely was a passing inflammation produced.

Details of Examinations.

The appended tables show the results of each day's examination of the hand and machine-drawn milks.

		HAND.		MACHINE.	
Date 1611.	Hours before plating.	Temperature of Milk. °F.	Number of Bacteria per c.c.	Temperature of Milk. °F.	Number of Bacteria per c.c.
Jan. 3	13	59	4,000	59	3,750
4	10	66	6,000	67	5,750
5	9	75	3,000	76	10,000
6	27	66	5,250	66	3,250
7	9	71	4,500	71	5,000
9	27	71	4,500	75	10,500
10	9	73	10,750	73	3,750
11	9	64	2,000	64	3,750
12	8	64	3,000	65	2,750
19	8	59	4,250	59	4,000
21	28	57	3,500	57	2,250
23	8	69	3,250	73	2,750
26	10	74	1,500	74	1,250
27	8	70	2,250	69	4,000
28	27	60	3,500	60	2,000
30	18	60	2,000	60	1,750
31	18	60	1,500	60	7,250
Feb. 1	18	55	2,750	55	13,780
2	18	55	1,250	55	9,250
5	18	53	1,750	55	6,750
6	18	51	5,250	51	137,000
7	18	53	9000	54	1,500
8	18	51	12,000	50	33,750
9	18	50	3,500	59	8,500
10	18	49	11,250	47	1,000
12	18	51	24,000	51	11,500
13	18	47	3,800	46	7,250
14	18	51	9,000	51	1,500
15	18	51	6,750	55	10,750
17	18	51	1,250	50	2,500
20	18	60	58,500	59	3,500

		HAND		MACHINE.	
Date 1911.	Hours before plating.	Temperature of Milk. °F.	Number of Bacteria per c.c.	Temperature of Milk. °F.	Number of Bacteria per c.c.
Fb. 21	18	55	3,500	55	1,000
22	18	55	6,500	71	4,000
23	18	55	15,250	59	5,000
24	18	49	7,000	51	3,500
26	18	49	2,500	51	3,250
27	18	55	7,000	55	1,000
28	18	54	9,000	53	15,500
Mch. 1	18	56	15,500	56	4,000
2	18	56	7,000	56	500
3	18	58	10,000	53	2,500
5	18	59	2,500	62	750
6	18	57	5,750	59	500
7	18	55	22,500	59	1,500
8	18	53	23,250	55	3,000
9	18	51	8,250	55	500
10	18	54	11,250	52	1,000
12	18	59	4,750	59	1,500
13	18	59	7,000	58	6,500
14	18	55	4,000	53	2,000
15	18	50	4,500	51	1,250
16	18	55	5,000	51	2,750
17	18	54	5,000	51	3,950
19	18	55	5,500	55	1,000
20	18	59	79,750	55	80,000
21	18	53	2,500	50	4,750
23	18	53	14,750	52	6,250
24	18	57	15,000	57	3,250
26	18	48	8,250	46	15,500
28	18	46	11,250	50	8,750
31	18	49	1,250	45	500
Apl. 2	18	58	5,000	59	750
3	18	67	1,000	65	250
4	18	56	250	57	1,250
5	18	52	500	55	5,000

		Hand.		**Machine.**	
Date 1911.	Hours before plating.	Temperature of Milk. °F.	Number of Bacteria per c.c.	Temperature of Milk. °F.	Number of Bacteria per c.c.
Apl. 6	18	52	*	53	*
7	18	53	500	56	26,000
9	18	51	*	49	1,250
10	18	50	*	51	6,000
11	18	49	250	49	*
12	18	47	250	47	2,250
17	18	56	*	57	*
18	18	52	*	52	*
19	18	50	*	50	*
20	18	44	5,600	44	*
21	18	46	5,750	47	250
24	18	50	1,800	49	1,250
25	18	48	1,400	49	2,400
26	18	52	2,250	52	1,000
27	18	52	4,500	52	500
28	18	52	6,000	52	3,250

NOTE.—* means less than 250 bacteria per c.c.

NOTES ON TABLES.

1. From January 3rd to January 28th the samples were taken from the morning milk.

2. From January 30th to April 28th the samples were taken from the evening milk.

3. From January 3rd to February 14th the machine milk was taken with the addition of the strippings drawn by hand.

4. From February 15th to April 28th the machine milk was taken without the addition of strippings.

5. From February 15th to March 20th the machines were used on test cows, immediately after removal from sterile solution.

6. From March 5th to April 28th the milk was delivered in ice chest as despatched from farm and without repacking.

7. From March 21st to April 28th the machines were used on test cows, after having previously milked 10 cows.

8. From April 9th to April 28th the cows were transposed as to method of milking.

On March 20th the excessive high count in both samples compared with previous and subsequent counts suggested that some unusual circumstances had been operating on the day in question. This view was confirmed by the fact that Dr. Bull's result from the same day's sample as sent to him from the ordinary supply was also unusually high. Careful inquiry led to the conclusion that on this particular day a certain batch of bottles had been ineffectively sterilised. In these circumstances that day's results have not been included in working out the average daily count of bacteria per c.c.

Results of Investigation.

The results of the above investigation have demonstrated the following points:—

1. That provided the apparatus of the milking machine is intelligently handled, and that it is thoroughly attended to as regards cleanliness and sterilisation, its use does not interfere with the general health of the cow or of the udder.
2. That the milking machine so used does not lead to a greater bacterial contamination of the milk than does the process of hand-milking, even when conducted under the most approved conditions, but that on the contrary the average results show an improvement.

In common with others, I have, however, noted in general practice that such pathological conditions as streptococcic mammitis, a common contagious disease of dairy cows, is much more readily spread by the milking machine than by the hand. As such a catastrophe can be readily obviated by a routine examination of each cow's udder prior to milking, a practice generally adopted by progressive dairymen, its occurrence should not be attributed to the machine alone, but to the carelessness or ignorance of its owner.

Given therefore the adoption of such precautions as are well within the compass of all dairymen, there appears to be no reason for anticipating any danger to the milking industry through the extension of the employment of such apparatus as approved milking machines when employed with due regard to their cleanliness and sterilisation.

This investigation was conducted at the Veterinary Institute of the Melbourne University, and I desire to express my thanks to Professor Gilruth (in whose laboratory the work was carried out) for much valuable assistance and advice; to Mr. H. R. Seddon, for help in the examinations; to Mr. W. A. McAdam, who so carefully superintended the operations on the farm, and to the Lady Talbot Milk Institute for providing the necessary samples of milk.

[Proc. Roy. Soc. Victoria, 24 (N.S.), Pt. II., 1911.]

Art. XXVIII.—*Enteritis, Associated with Infection of the Intestinal Wall by Cyst-forming Protozoa (Neosporidia), Occurring in certain Native Animals (Wallaby, Kangaroo and Wombat).*

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and

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(With Plates LXXII-LXXXI.).

[Read 14th December, 1911].

For some considerable period post-mortem examinations have been made at the University Veterinary Institute of the majority of native animals which have died at the Zoological Gardens, Melbourne. Quite recently several cases of more or less acute enteritis, evidently the immediate cause of death, have been observed, and in each of these extensive invasion of the mucosa or submucosa by protozoa has been detected on microscopical examination.

As will be seen, the protozoan infection in all cases, with the exception of one wallaby, was very extensive, and must have been in existence for a considerable period prior to death. Obviously, therefore, to this infection the acute inflammation cannot be entirely attributed. It is especially worthy of note that in every instance the animal was a recent arrival at the Zoological Gardens, having been captured, conveyed to Melbourne, and delivered apparently in normal health. Probably the confinement, coupled with the drastic change of food and environment, enabled bacteria to invade the damaged and weakened intestinal wall, and so established the acute enteritis, the immediate cause of death, for even in those cases where post-mortem examination was made a few hours after death, extensive bacterial invasion of the intestinal coats was very definite. It may be that more extended investigation of further cases will demonstrate that these parasites which at present appear to be of four distinct species, possibly a new genus, are but the one species varying according to the animal and according to the cells invaded. The terms applied to these protozoa in this article are therefore naturally provisional, and in the absence of full knowledge of their life history are only employed to avoid confusion and repetition in future references.

So far as we are aware, such parasites have not previously been recorded, though that referred to as *Sarcocystis mucosa*, Blanchard, by Ray Lankester (Treatise on Zoology, Part I., p. 351), and by Guiart (Parasitologie, p. 239), who includes it with the sub-genus *Balbiania*, may prove on consulting Blanchard's original memoir, which at present is not available, to be the same as one or other of the forms we describe.

SARCOCYSTIS MACROPODIS from Wallaby (Petrogale sp.).

The protozoan infection has been observed in three animals. In two cases the immediate cause of death was acute enteritis, affecting the greater part of the small intestine in each, the parasitic cyst being confined to the inflamed portions, and present in enormous numbers, but in the other specimen there was no acute inflammation, while the cysts were very few in number, not more than a dozen being present in the whole of the intestinal wall. In this note those manifesting the acute enteritis are alone dealt with.

On post-mortem examination the whole of the small intestine was observed to be mottled with irregular areas of deep congestion, visible from the serous surface. On closer examination these areas were seen to be composed of groups of fairly regular circular nodules with pale centre surrounded by a deeply congested periphery. The whole mucosa on incision was found to be catarrhal and deeply congested, especially around and above the small nodules, which distinctly projected into the lumen as dark red elevations each about the average size of a grain of mustard. The stomach and large intestines were normal, as were the other viscera, with the exception of one mesenteric lymph gland, which showed enlargement and hyperaemia, and on section was found to be mottled with numerous circular greyish areas, pinhead or smaller in diameter, due to proliferation of groups of fixed cells surrounded by a zone of closely packed lymphocytes.

The small intestinal nodules could be removed from the submucosa in which they were situated with some difficulty. They then presented a translucent cystic appearance, and could be readily squeezed and ruptured between two slides. Examination of the smears made in this fashion demonstrated the presence of spindle-shaped nucleated sporozoites, similar in many respects to the spores of sarcosporidia.

In sections of the intestines examined under the low power of the microscope, the submucosa is seen to be greatly thickened by spherical masses of new, loose, fibrous tissue enclosing distinct parasitic cysts (Plate LXXII., Figs. 1 and 2), which are so numerous that in many parts a single field shows from ten to twelve. These cysts, together with the surrounding inflammatory tissue, may be found singly or clustered together, in some cases the mucosa being so implicated as to result in complete atrophy of the muscularis mucosa (Plate LXXIII., Figs. 3 and 4). The periphery of the new inflammatory tissue is extremely vascular, the capillaries being greatly distended with blood, and haemorrhages are frequent. In certain regions, especially where the cysts are numerous and close together, there is atrophy of Lieberkühn's glands, and even complete disappearance of many villi. The mucosa is congested, and there is complete denudation of the surface epithelium, even in the specimens fixed very soon after death of the animal.

The parasitic cysts vary considerably in size, generally according to the stage of development: the younger stages observed vary from 0.15 mm. to 0.26 mm.; the intermediate stage from 0.3 mm. to 0.5 mm.; and the mature cysts from 0.36 mm. to 0.7 mm. in diameter. They are roughly spherical as a rule, but individual specimens in which there is considerable distortion are not uncommon.

For purposes of description the parasite may be divided into envelope and contents.

The envelope consists of two zones, an external radiate and fringe-like, and an internal on which the fringes of the outer zone rest, uniform in thickness and staining deeply. The external "fringe" is fairly uniform in breadth, averaging 20 μ in the younger stages (Plate LXXIV., Fig. 2), but in the older stages it is extremely irregular, especially at certain situations where it sends out long branching and anastomosing processes into the surrounding tissue, and is invaded by polymorphs (Plate LXXIV., Fig. 6), of which, immediately around nearly all cysts, there is a distinct accumulation.

The contents consist of a homogeneous endoplasm, uniformly staining, but for faint concentric striations probably due to contraction in fixing. Towards the centre of this endoplasm are situated numerous blastophores, more or less spherical areas without a limiting membrane containing nuclei, which gradually develop into mature spores. The younger the parasite the greater is the amount of endoplasm present, and in the earliest stages observed it not only distinctly separates each blastophore from its neighbour, but more completely separates the most peripheral of the blastophores from its envelope. As the cyst develops, however, the endoplasm becomes reduced, ultimately the blastophores generally, though not always, lying close together, and immediately underneath the inner zone of the envelope (Plate LXXV., Fig. 7). Both the envelope and the endoplasm stain definitely with eosin, and such acidophile dyes.

The blastophores within the endoplasm vary considerably in number, the average being from 60 to 80 in a median section. What may be described as three distinct stages are observed. In the youngest cysts (measuring from 0.0134 mm. to 0.0335 mm. in diameter) they are irregularly but more or less centrally grouped. The nuclei, which vary from 7 to 20, are peripherally arranged, and lie in a fine granular basophile material. The second stage shows an increase both in size (0.225 to 0.0584 mm.) and in the number of nuclei, the granular material being separated into masses around which the nuclei are arranged. These masses seem to divide as the nuclei further increase and ultimately each blastophore is crowded with nuclei still arranged mulberry-like around small portions of the granular material. In the third stage (0.0334 to 0.075 mm.) of the development, the nuclei are seen to develop small peripheral cones of finely granular protoplasm; gradually the central mass divides until in this manner fully-developed spores are formed, these being crowded together within the enlarged blastophore (Plate LXXV., Fig. 7), but still in most cases grouped radially around a varying quantity of residual protoplasm. In some sections free spores may be seen exterior to the cysts, these having escaped through the now thin and ruptured envelope.

Degeneration of the Blastophores.

What is apparently a degeneration of some of the blastophores is of frequent occurrence, for in all stages of development of the cysts one or more spaces may be seen which correspond to the blastophores, but are generally much larger and usually situated at or near the centre of the cyst. These spaces contain a loose basophile granular material, evidently the chromatin of broken-down nuclei. Different phases of the nuclear disintegration may be seen in various cysts.

Mature spores.

These are best examined in smears prepared by squeezing the contents of the cysts between a coverglass and slide, fixing in alcohol, and staining by giemsa or iron haematoxylin and eosin. Spores thus fixed and stained are found to be ovoid or falciform bodies narrowing towards one end, and measuring 7.3μ to 12.4μ long by 3.4μ to 4.9μ broad. A large nucleus situated rather nearer the narrower extremity than the centre. In no instance does the nucleus stain deeply, and often it is less definitely stained than the cytoplasm, appearing as a somewhat clear ovoid space of nearly the same diameter as the spore. Scattered throughout the cytoplasm are numerous granules situated chiefly towards the blunter and broader end.

ILEOCYSTIS MACROPODIS and LYMPHOCYSTIS MACROPODIS in Kangaroo (Macropus sp.).

The infection has been observed in only one specimen, a young, half-grown kangaroo, which died a few days after arrival from Gippsland, where it had been captured. The carcase showed evidence of very acute diarrhoea, indeed dysentery, having been present prior to death. Post-mortem examination showed intense haemorrhagic inflammation of the greater part of the intestines, commencing about eighteen inches from the pylorus, as small and scattered petechiae, gradually becoming more numerous and ultimately confluent further along the canal. The caecum was but slightly affected, and the inflammation gradually disappeared in the large intestine, the rectum being normal. The intestinal contents were fluid, and mixed with much blood, the result of numerous haemorrhages. The inflammation, though chiefly confined to the mucosa, yet implicated to some extent all the coats of the viscus. From the serous surface no nodular appearance was visible, but on washing the intensely catarrhal mucosa, it was seen to be affected with numerous irregular greyish granular elevations. The mesenteric lymph glands were all oedematous and haemorrhagic, especially the colic gland, which was greatly enlarged and intensely haemorrhagic throughout.

Smears of the intestinal contents showed on microscopical examination innumerable falciform bodies (similar to those of sarcosporidia) to be described later.

Sections of the intestine examined microscopically show great distension of the smaller blood vessels, especially of the mucosa and very frequent haemorrhages. The villi, and indeed the whole mucosa, are much swollen, and close examination demonstrates the presence of two forms of parasitic cysts, some very large and closely packed in groups, and others very numerous, much smaller, and loosely scattered. There is but little tissue reaction, but the larger cysts are generally surrounded by a zone of leucocytes, and some new inflammatory tissue, though small in amount. The larger cysts are almost confined to the deeper areas of the mucosa (Plate LXVII., Fig. 11), but the small "cysts" are distributed fairly uniformly throughout the mucosa, even almost to the apices of the villi, often over considerable areas being entirely unassociated with the large cysts. As these varieties of "cysts" differ in many respects they must be described separately.

Large Cysts. Ileocystis macropodis.

These may be found singly, but generally in groups or clusters of three to eight (Plate LXXVI., Figs. 2 and 10). At times irregular in size, they are generally fairly uniform, when the appearance is that of a circular mass divided distinctly into three or more triangular segments, each with a crescentic base. These groups vary in size from 0.07 to 0.334 mm. in diameter. Like the wallaby cysts, each is provided with an envelope and with a homogeneous endoplasm within which is situated one blastophore (or perhaps schizont). The envelope shows at the free edge a fringe-like external coat, of an average breadth of 8μ, the striations being much finer and more regular than in the wallaby cysts. There is a definite thin inner coat, staining faintly blue with haematoxylin and eosin, and brownish with Van Gieson, while the bases of the fringe form at their junction a faintly staining intermediate zone, into which the striations are seen to prolong. The fringe and the endoplasm are acidophile, the former staining the less deeply. Where two cysts approximate the fringe is lost, but the faintly staining intermediate zone can be seen to extend between the two adjacent cysts, separating the endoplasm of the one from the other, and varying in breadth in the different groups (Plate LXXVIII., Fig. 12).

Within the endoplasm, lying almost invariably next the crescentic free border, lies always (as can be seen in serial sections) a large granular deeply staining body, which varies in shape: in the smaller cysts it is irregularly spherical, and exceeds in size the blastophore, in the larger cysts it is in the form of a long triangle or narrow long spindle (Plate LXXVI., Figs. 9 and 10). This body is probably the hypertrophied nucleus of the original cell, and indeed what appear to be the large spherical nucleoli can often be detected among the deeply staining granular material. These nuclei vary in size greatly, being in the younger cysts 14.6μ in diameter, and in the oldest from 79.2μ to 95.9μ long, and 8.34μ to 18.7μ broad. At first we were inclined to the opinion that these peripheral deeply staining masses were degenerated blastophores similar to those seen in the wallaby, but the fact that in serial sections each cyst is found to be definitely associated with one of these masses, and that they are always in the same situation negatives such a view.

In the early stages the blastophore or schizont appears as a faintly staining space (12.8μ to 15μ in diameter) crowded with nuclei (1.7μ in diameter), and surrounded by endoplasm. As the parasite increases in size these nuclei multiply greatly, the cell nucleus becoming definitely pushed to the pole furthest from the centre of the group. The nuclei of the parasite are at times seen arranged around a central mass mulberry fashion, but often no such arrangement is distinct. Gradually they become surrounded by a spindle-shaped mass of faintly-staining protoplasm with blunt ends, and no definite markings, attaining in size 4.3μ to 4.7μ long, by 1.7μ to 1.9μ broad. In none of our sections are the spores of these large cysts seen to be mature, and there is no evidence of rupture.

Small Cysts. Lymphocystis macropodis.

(Although for purposes of description these are here so termed, we recognise that the parasites in question cannot, strictly speaking, be classed as "cysts.")

All the villi in our sections, as already stated, are greatly swollen, and almost all are denuded of epithelium. The majority are crowded especially towards the base with large cells 8.4μ in diameter, containing parasites, which have pushed the nucleus to one side (Plate LXXVIII.,Fig. 13). In these parasites nearly all the stages of schizogony, from that of division into four nuclei, can be observed, although rarely in the one field. Plate LXXIX., Fig. 14, shows the various stages as observed, drawn under the camera lucida. The nucleus soon after invasion of the cell by the parasite becomes enlarged and pushed towards the periphery. In the earliest stage of the parasite we have observed, viz., with four nuclei (1.7μ in diameter), the cell nucleus though enlarged is but slightly eccentric. When situated at the very edge, the nucleus may seem at first sight irregular, but careful focussing demonstrates it to be saucer-shaped and clasping the cell. As the parasite grows, the nuclei multiply, and the schizont gradually fills the cell, which becomes enlarged to three or four times the original diameter, the cytoplasm forming an envelope of the cyst, with the enlarged flattened and elongated cell-nucleus at the edge (Plate LXXIX., Fig. 14). On cessation of multiplication the nuclei gradually become surrounded by protoplasm, and develop into spindle-shaped merozoites (4.3 to 5.5μ long by 2.1 to 2.5μ broad), which, when mature, escape through the attenuated and ruptured cystic cell wall, and may be seen lying free between cells, invading lymph spaces, and even small blood-vessels, and within the lumen of the intestines, these last being the spores observed in the original intestinal smears. Groups of the free spores are to be found within the enlarged and congested mesenteric lymph gland, noted on post-mortem.

As to the nature of the body cells invaded by these two different parasites, it seems to us that in the case of the large cysts they are epithelial in nature, and in the small "cysts" leucocytes. With the large cysts in the absence of the very early stages it is impossible to be dogmatic, but the arrangement and the situation, which is never below the line of gland acini, suggests a simultaneous invasion of a number of epithelial cells in a duct or acinus of Lieberkühn, which would account for the grouping and the peripheral distribution of the cell nuclei. In a very few cases we have observed a single cyst at the edge of a villus which also supports this view.

As in the small "cysts," the cells so definitely invaded are certainly not epithelial, for they are always situated within the basement membrane of the villi. Comparing these cells in the very earliest stages of infection with cells within unaffected villi, and with cells in normal villi, there seems to be no doubt that they are mononuclear leucocytes (Plate LXXVIII., Fig. 13).

Free Spores in Intestine. (Plate LXXIX.).

Smears of the contents of the whole intestinal canal except those of the rectum, especially those smears made from the material immediately covering the mucous membrane, show enormous numbers of spores, evidently those liberated on maturing of the smaller parasites. These spores are much larger than those seen in sections probably owing to the better fixing preventing contraction. The spores are ovoid or spindle-shaped—10.7 to 12.4μ long, by 2.78 to 4.25μ in greatest breadth. Generally one extremity is broader than the other, and stains more deeply. The nucleus is large, stains deeply with iron haematoxylin, and is usually situated towards the broader end of the spore. A few minute granules are to be found, situated chiefly towards the narrower part of the spore.

ILEOCYSTIS WOMBATI in Wombat (Phascolomys latifrons).

Unfortunately this animal could not be examined until a lapse of 24 hours after death, consequently the results are not nearly so satisfactory as in the case of the other animals. In view, however, of the pathological and parasitic conditions being similar in many respects to those described in the other native animals, though differing in important details, it is thought they are worthy of record.

The wombat, an adult, had reached Melbourne but a few days prior to death. On exposure of the abdominal viscera the small intestine presented a peculiar reticular mottled appearance. The mucosa on incision was seen to be greatly thickened, the surface being wrinkled in the form of a fairly regular network. On removal of the catarrhal material which covered the surface, this condition was especially noticeable on placing a portion of intestine in water, when the general appearance was that of a thick grey fur.

Only the small intestine was affected, and practically in a uniform manner, the stomach as well as the large intestines being free of any abnormality.

Sections examined microscopically show the pathological changes to be confined to the mucosa and sub-mucosa. The villi are greatly hypertrophied more or less uniformly throughout, but at different points there is much hyperplasia of the underlying connective tissue, giving the wall a papillomatous appearance, and accounting for the reticular, wrinkled conditious so apparent to the the naked eye (Plate LXXX., Fig. 16).

The villi are almost entirely denuded of epithelium, and the great majority of Lieberkühn's crypts are obliterated, only a few of the acini being left. The new connective tissue under the high power is seen to be distributed in true papillomatous fashion, sending into the lumen of the intestine long processes carrying the hypertrophied villi. These villi in turn are greatly distorted by the presence of large numbers of parasitic cysts (Plate LXXX., Fig. 16), which differ from any of those previously described. These cysts are generally attached to the surface of the villi, which are otherwise denûded of epithelium, but here and there they are to be found crowding and distending the glands of Lieberkühn when they are surrounded by more or less new inflammatory tissue (Plate LXXX., Fig. 17). In none of the sections made from different parts of the intestine are mature cysts seen. On the contrary by far the greater number are evidently degenerated, the contents consisting simply of a granular homogeneously staining material. That this degeneration is not due to the lapse of time after death of the host before the tissue was fixed is evident from the irregular distribution of the living and degenerated cysts (Plate LXXX., Fig. 17, and Plate LXXXVII., Fig. 18). In both cases there is often considerable shrinking of the cystic contents from the wall which is more definite in the degenerated cysts than in the others, and may be to some extent due to fixing. The living cysts which are usually the larger are composed of a thin envelope and an endoplasm, containing many small nuclei (0.85μ to 1.48μ). They are spherical or ellipsoidal, measuring from 0.093 mm. to 0.113 mm. in greatest diameter. The envelope is thin and shows no brush-like arrangement, and in few can any remains of an original cell nucleus be determined. The endoplasm consists of a homogeneous or faintly granular material, staining with eosin and such stains, amongst which in the earliest stages observed are scattered the minute deeply staining nuclei. These nuclei may be arranged without apparent order, but are usually grouped around masses of the protoplasm, and appear as circular, oval, and at times reticulated areas. No further stage of development has been detected in any of our sections.

As the cyst increases in size it should be noted that the nuclei become smaller and more irregularly arranged, so much so that the largest cysts consist of a very thin ectoplasm, containing minute cocci (0.8μ in diameter).

In the earlier stages of the cysts degeneration is much more common than in the later stages, the larger cysts. Here the contents show no nuclei, but simply a granular mass, which stains deeply with eosin, and with the picric acid of Van Gieson stain. The surrounding envelope is thicker in all the earlier stages of the parasite whether degenerated or not, and often a fairly distinct nucleus with definite single nucleolus of the original cell can be observed, both in the degenerated and the living early stages. In the earliest stage noted, the parasite partly degenerated, is situated close to the nucleus, and in the centre of a roughly triangular epithelial cell (45.8μ by 35.4μ) the protoplasm of which completely surrounds the parasite (Plate LXXVII., Fig. 18).

Unhappily, owing to the unavoidable delay in fixing, neither the cell nucleus nor the nucleolus stain definitely or deeply with nuclear stains. It may be therefore that these cysts are not degenerated, but simply a still earlier stage of the parasites' development than that previously described, but at present the evidence is against this supposition.

General.

The large cysts described in the kangaroo, the wombat, and probably also those of the wallaby, although situated beneath the muscularis mucosae, are similar in many respects to the *Gastrocystis gilruthi*, Chatton, 1910, affecting the abomasa of sheep and goats, originally discovered by one of us, and carefully studied by Ed. Chatton. These cysts, which are to be found present in the glandular mucosa of the majority of ovine stomachs, and visible to the naked eye as minute elevations, are composed of an envelope and contents, the latter varying according to the maturity of the parasite (Plate LXXXI., Figs. 19-20). The envelope is formed by a gigantic single cell (parietal cell), and the external surface of the envelope or cell is provided with a uniform very fine brush-like fringe "which ensures an intimate contact and facilitates exchanges with the surrounding tissue." The fringe measures 7 to 9μ in thickness. The flattened and greatly enlarged nucleus of the epithelial cell persists at some part of the periphery and causes a notable thickening of the wall. The chromatin is spread throughout the nuclear space as granular cords very irregularly anastomosing surrounding the enlarged homogeneous nucleoli.

In mature cysts the contents are formed by innumerable fusiform germs, 10μ by 1.5μ, each of which contains a definitely staining oval nucleus situated near one extremity, and a small centrosome. Generally the nuclear extremity is blunter than the other, which is abruptly narrowed. These germs are arranged radially around a residual mass which gradually disappears as they mature.

In the earlier stages of the cysts observed by Chatton there are three distinct zones; one internal condensed, a median zone of clear cytoplasm, and an external thin zone, formed by the juxtaposition of the roots of the "fringe." The contents consist of a plasmodial mass in which lie numerous glandular nuclei without definite membrane. These nuclei are grouped in divers manners but not without order. Some are arranged as morula, some as large spheres or ellipses, some in groups of two or three or four, etc., but even isolated nuclei may be seen. As the cyst matures the cytoplasmic masses contained in these nuclear morula condense, while the interstitial cytoplasm rarifies. The groups of nuclei then form blastophores, of which all the nuclei are regularly arranged at the surface under a fine membrane or envelope. In all these blastophores simultaneously above each nucleus a small cone of protoplasm appears. These cones increase in size, and gradually form the fusiform germs. In the larger masses all the nuclei do not form germs, a certain number remaining in the residual protoplasm, which itself as well as the interstitial cytoplasm becomes completely absorbed during the maturation of the cysts (Plate LXXXI., Figs. 19-20 c.). It will be seen from this précis of Chatton's work how similar in many respects is the early stage of development of the *Gastrocystis* to that of the large cysts, particularly those of the kangaroo and of the wombat which we have described, and even to some extent of the wallaby cyst.

Chatton discusses the enlargement of the epithelial cells as a result of the invasion by the parasite. He admits that because of its dimensions, its structure, and especially the fringe-like peripheral arrangement it does not appear at first sight a modified gland cell. He points out that many gregarines and coccidia produce great hypertrophy of affected cells, and so far as the "brush" is concerned recalls that Mrazek maintains this is so in the lymphocytes of *Oligochetes* infected by Microsporidia, and that according to him the myxocystis of which the characteristics are a superficial brush, and two kinds of nuclei, is in reality a complex body formed by a lymphocyte greatly hypertrophied, and by the microsporidium, to the lymphocyte belonging the fundamental mass of the myxocysts, the large nuclei and the peripheral fringe, while to the microsporidium belong the small elements and the spores derived therefrom.

There are many resemblances between the sarcosporidia, and the cysts we have described as well as the *Gastrocystis gilruthi*. The sarcosporidia in the pig (*Sarcocystis miescheri*) also possess a peripheral "fringe," even in the mature cyst. There is also great similarity between the mature merozoites of these parasites and the falciform corpuscles of the sarcocystis, even greater than between the latter and those of the *G. gilruthi*.

Summary.

In this communication what appear to be four varieties of pathogenic neosporidia are described as seen in intestinal affections of three different genera of native fauna.

1. In the wallaby the parasite (*Sarcocystis macropodis*) is situated in the submucosa, and is surrounded by chronic inflammatory tissue. It is composed of an envelope with fringed periphery, and an endoplasm separating the blastophores, which in the earlier stages are composed of nuclei arranged peripherally around masses of protoplasm, and in the later stages of mature spores, similar to those of sarcosporidia. No nucleus of an original tissue cell can be detected. But assuming the cyst to be derived from an invaded body cell greatly hypertrophied, this cell does not appear likely to be epithelial in character, but probably a lymph or endothelial corpuscle. As in *Balbiania* the origin may be a muscle fibre, but the sections do not support such a view.

2. In the kangaroo there are apparently two parasites. The larger *Ileocystis macropodis* are generally present in groups. Each possesses an envelope with a regular fringe at the periphery, and a small

amount of endoplasm surrounding innumerable nuclei, which in the earlier stages are irregularly distributed, but in the later stages are arranged around masses of protoplasm. Within the endoplasm, lying close to the envelope of each cyst, at the pole furthest from its neighbours, lies an irregularly spherical, oval or crescentic deeply-staining granular body, which is probably the greatly hypertrophied nucleus of the invaded cell. The majority of these large cysts are situated at the base of a villus, but occasionally some may be seen (generally singly) nearer the apex, situated always at one side of the villus. Assuming that these represent greatly hypertrophied body cells the indications are that they are epithelial in type.

The smaller "cysts" (*Lymphocystis macropodis*) are situated underneath the basement membrane of the mucosa, and are definitely formed within invaded cells, probably mononuclear lymph cells. The cell-nucleus, even in the very early stages, when the parasite consists of but four small nuclei surrounded by a faintly staining spherical mass of protoplasm, is distinctly pushed to the side of the cell, and becomes hypertrophied as the cell increases in size owing to the growth of the parasite, ultimately becoming saucer-shaped, clasping the periphery of the cell. The nuclei of the parasite multiply greatly, do not become regularly arranged, and finally form falciform spores, which escape from the mature cyst into the lumen of the intestine on the one hand, and into the lymph stream on the other, as a result of which they may be found in adjacent lymph glands.

3. In the wombat (*Ileocystis wombati*) the cysts are arranged around the periphery of the villi, and within the glands of Lieberkühn. They are present in enormous numbers, and induce a papillomatous condition of the mucosa similar to severe coccidial infection. The majority of the glands are completely obliterated by the infection and by the tissue reaction, while the villi are enormously hypertrophied. Many of the smaller cysts appear to be degenerating, and these show a definite envelope, frequently containing an enlarged cell nucleus, with single spherical nucleolus. The living cysts are usually much larger, have a thin envelope, with seldom any definite nuclear body, and an endoplasm containing in the early stages irregularly-distributed minute nuclei, which, as the parasite develops, become arranged

in more or less spherical mulberry groups, around masses of endoplasm. That here we have an invasion of the epithelia there is little reason to doubt. Unfortunately no fully-developed spores can be found, so that the mature stage of the parasite remains unstudied.

These parasitic protozoa affecting the intestines of different Australian native animals appear to be of species hitherto undescribed.

Judging from the appearance and the situations especially, probably four new species have been encountered. That they can hardly be included with the *Sarcosporidia*, is evident from their situation, and from their general structure. There is no doubt that even the wallaby cysts have not their commencement in muscle cells, for they, in the early stages, are seen to be quite apart from any of the muscle coats. The kangaroo large cysts are probably within epithelial cells, while the smaller cysts are definitely within mononuclear leucocytes. The wombat cysts are undoubtedly in epithelial cells. The nature of the cysts is in no case similar to the sarcosporidium. Each may, however, be included in the same class *Neosporidia.*

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DESCRIPTION OF PLATES.

Plate LXXII.

Fig. 1.—Wallaby cyst. Almost mature stage, showing irregularity of fringe and distortion of cyst with surrounding inflammatory reaction and situation. (Drawn by aid of camera lucida.)

Fig. 2.—Wallaby cyst, early stage. (Drawn by aid of camera lucida.)

Plate LXXIII.

Fig. 3.—Wallaby. Oblique longitudinal section, showing groups of cysts in various stages of development, with surrounding inflammatory tissue. (*a*) muscle coats, (*b*) mucosa, (*c*) groups of cysts, (*d*) inflammatory tissue. (Photomicrograph × 18).

Fig. 4.—Wallaby. Transverse section of intestine, showing many cysts. (Photomicrograph × 18).

Plate LXXIV.

Fig. 5.—Wallaby. Edge of young cyst, showing regular fringe, endoplasm and blastophores. (Photomicrograph × 420).

Fig. 6.—Wallaby. Edge of mature cyst, showing very irregular fringe, with atrophy of muscular and mucous coats. (Photomicrograph × 460).

Plate LXXV.

Fig. 7.—Wallaby cyst. Blastophore, showing mature spores with masses of residual protoplasm. The radial arrangements of the spores has disappeared, and the masses of residual protoplasm are unusually large. (Drawn by the aid of camera lucida.)

Fig. 8.—Wallaby. Mature spores of parasitic cysts, drawn from smears. (Drawn by aid of camera lucida.)

Plate LXXVI.

Fig. 9.—Kangaroo. Section showing two groups of large cysts. (*a*) early stage, (*b*) stage of almost maturity, showing hypertrophied and cresentic cell-nuclei at periphery (*c*) groups of small "cysts" in vicinity. (Photomicrograph × 110).

Fig. 10.—Kangaroo. Groups of large cysts, showing hypertrophied cell nuclei. (Photomicrograph × 340).

PLATE LXXVII.

Fig. 11.—Kangaroo. Section of intestine, showing—(*a*) groups of large cysts, and (*b*) hypertrophoid villi. (Photomicrograph × 70).

Fig. 18.—Wombat. Section showing—(*a*) degenerating cysts, (*b*) cell nucleus, (*c*) large living cyst, (*d*) unaffected crypts of Lieberkühn. (Photomicrograph × 370).

PLATE LXXVIII.

Fig. 12.—Kangaroo. From section: group of hypertrophied cells invaded by large parasites—(*a*) cell showing nucleus and parasite, (*b*) cell showing parasite, but no nucleus, (*c*) cell showing nucleus, but no parasite, (*d*) cell showing neither nucleus nor parasite (*e*) fringe. (Drawn by aid of camera lucida.)

Fig. 13.—Kangaroo. Cross section of villus showing schizonts within mononuclear lymph cells. (Drawn by aid of camera lucida.)

PLATE LXXIX.

Fig. 14.—Kangaroo. Development of small schizonts within monoculear lymph cells. (Drawn by aid of camera lucida.)

Fig. 15.—Kangaroo. Mature spores of small cysts. (Drawn by aid of camera lucida.)

PLATE LXXX.

Fig. 16.—Wombat. Section of intestine showing papillomatous condition with parasitic cysts in mucosa. (Photomicrograph × 18).

Fig. 17.—Wombat. Section of mucosa, showing—(*a*) large living cysts, (*b*) smaller degenerating cysts, (*c*) unaffected crypts of Lieberkühn. (Photomicrograph × 90).

Plate LXXXI.

Fig. 19.—Wombat. Degenerating schizonts within epithelial cells. (Drawn by aid of camera lucida.)

Fig. 20.—*Gastrocystis gilruthi*, Chatton.

A. Within mucosa of abomasum of sheep. Plasmodial stage before spore formation, while zone around the cyst represents the fringe. At the right is situated the hypertrophied nucleus of the invaded parietal cell.

B. Mature spores.

C. Formation of spores of a blastophore. (After Chatton.)

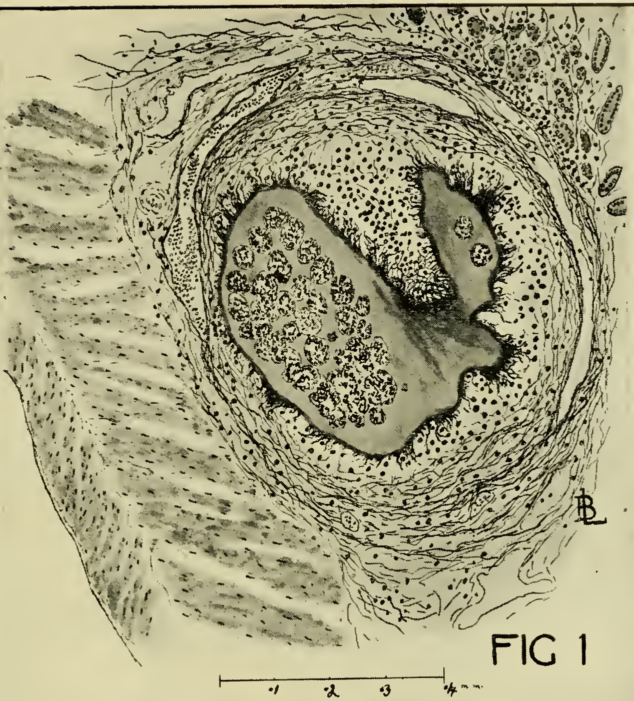

FIG 1

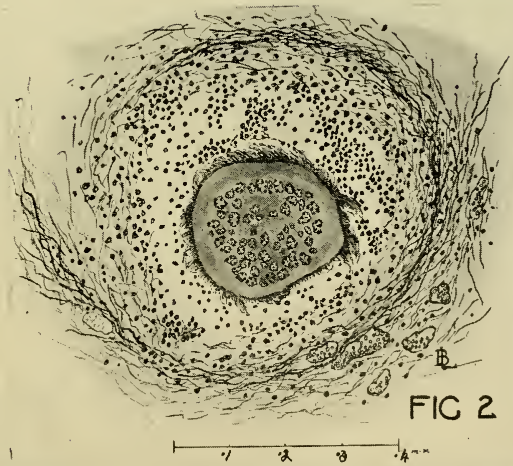

FIG 2

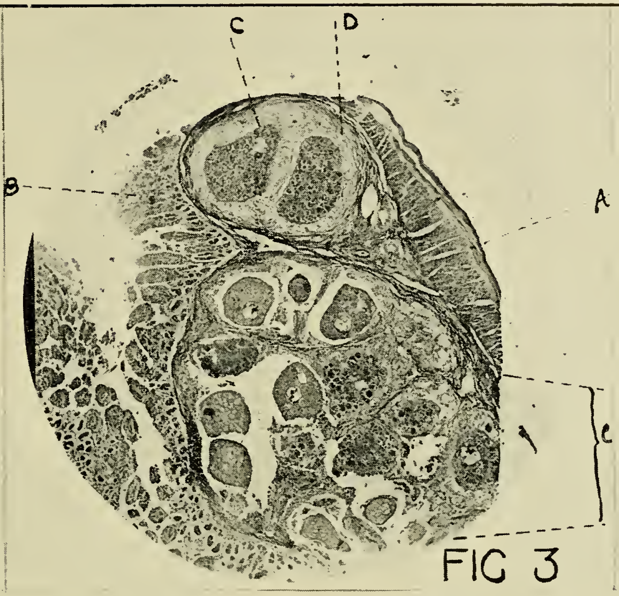

FIG 3

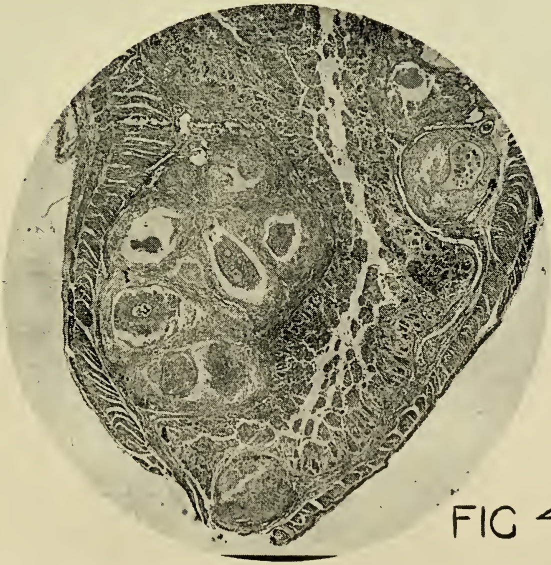

FIG 4

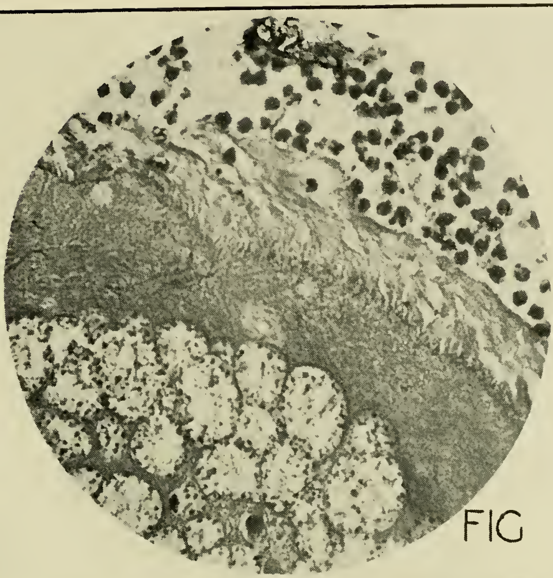

FIG 5

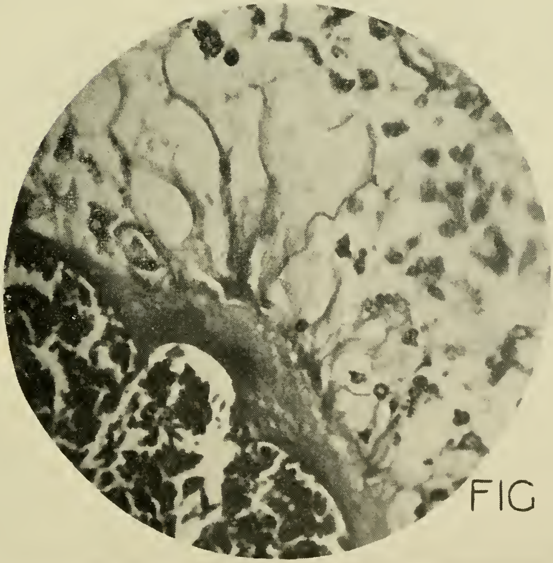

FIG 6

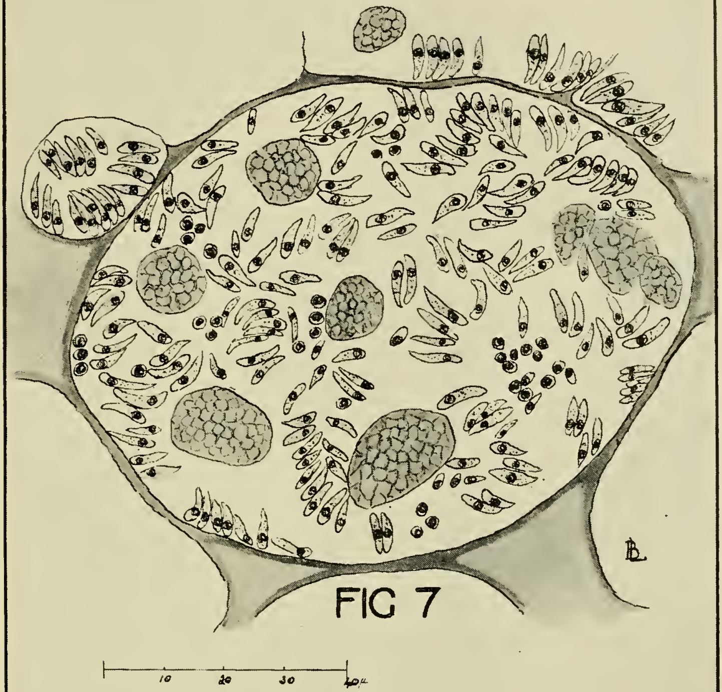

FIG 7

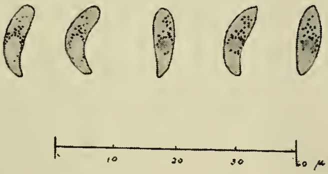

FIG 8

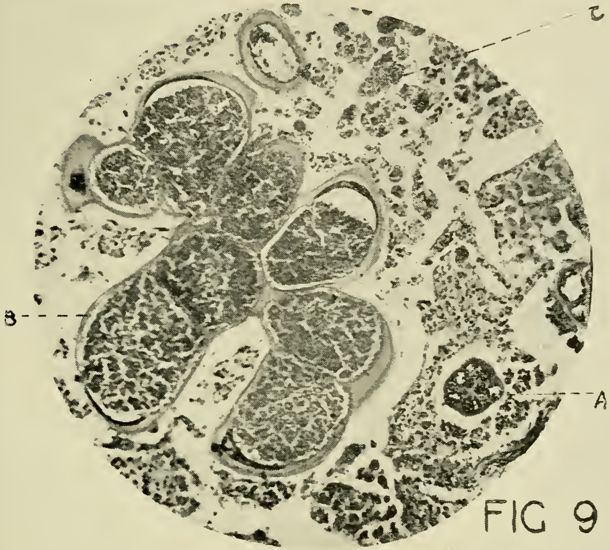

FIG 9

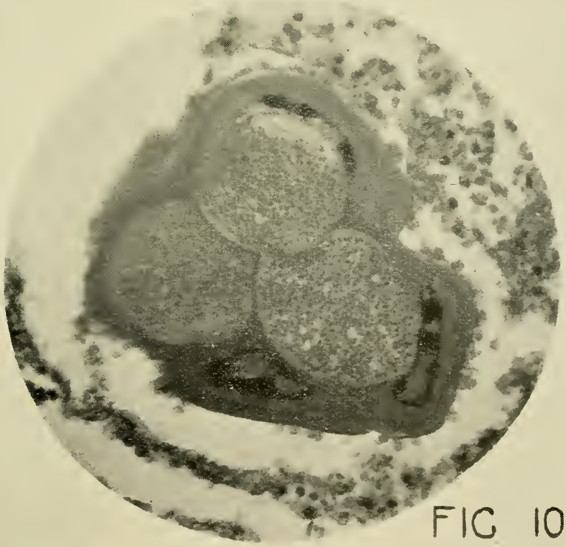

FIG 10

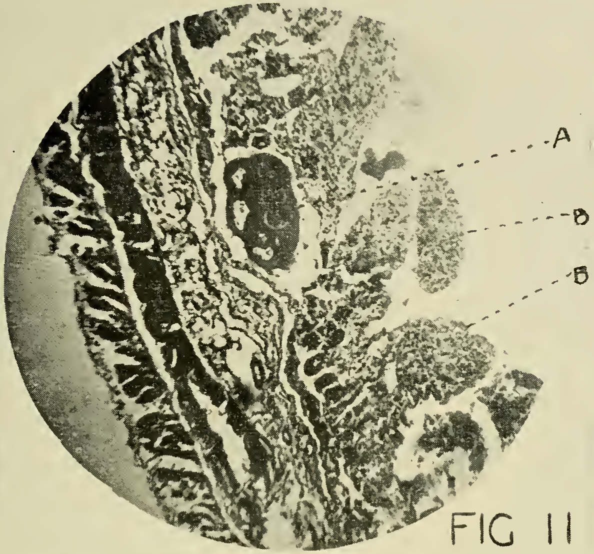

FIG 11

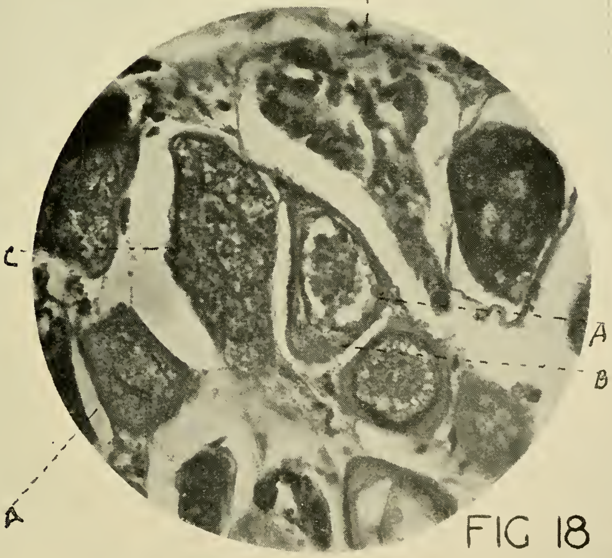

FIG 18

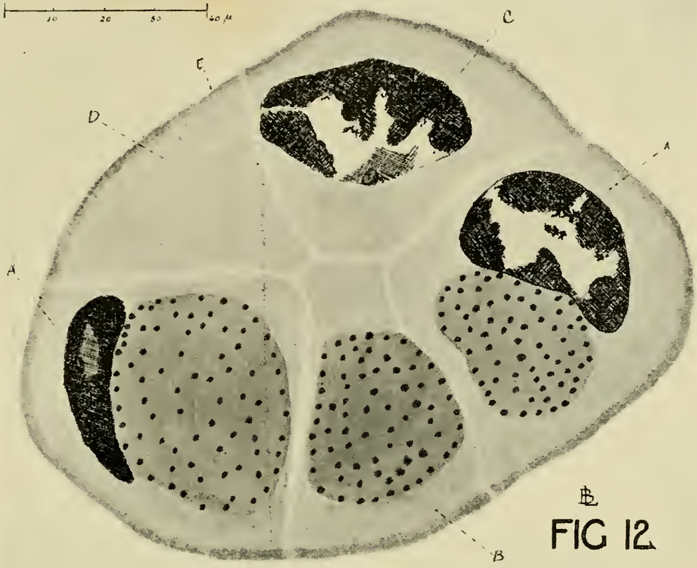

FIG 12.

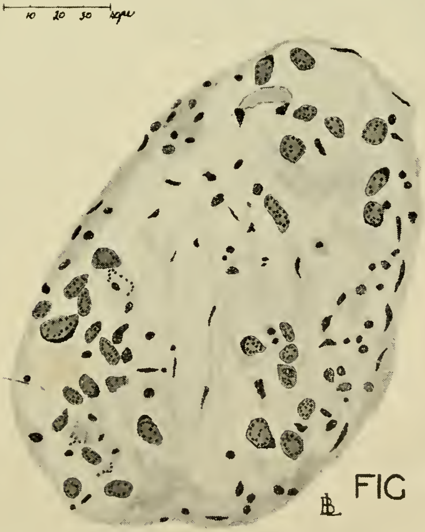

FIG 13

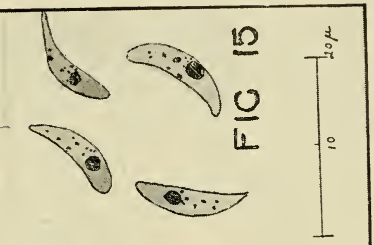

FIG 15

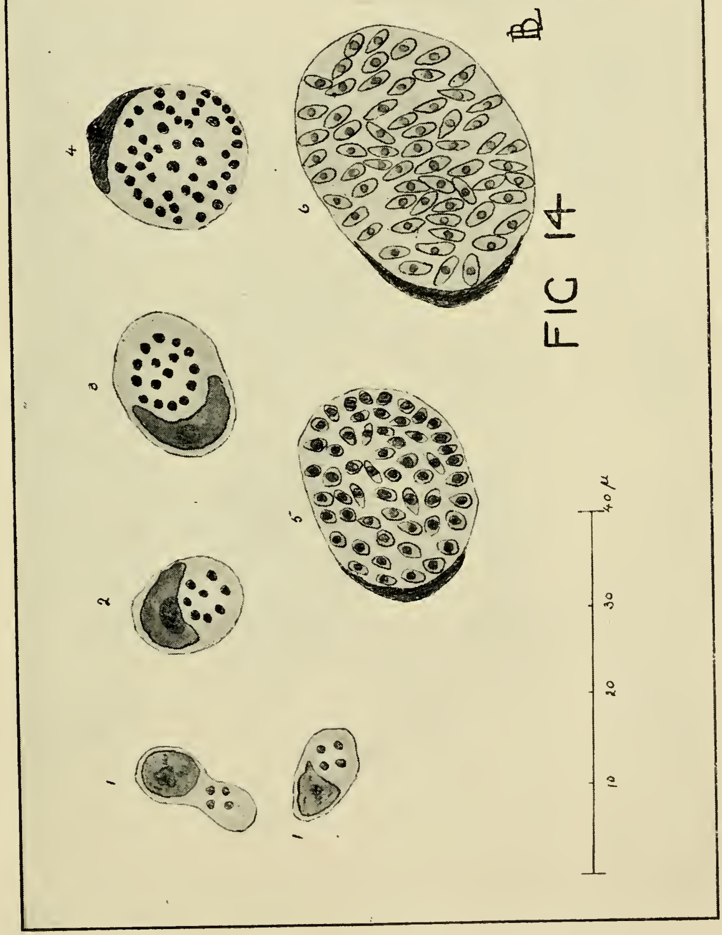

FIG 14

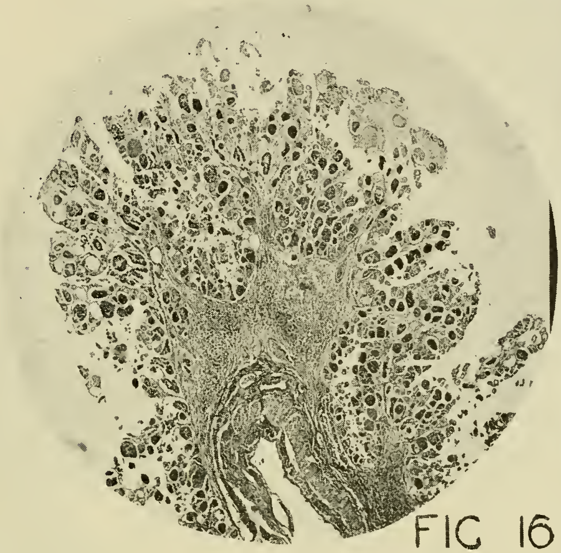

FIG 16

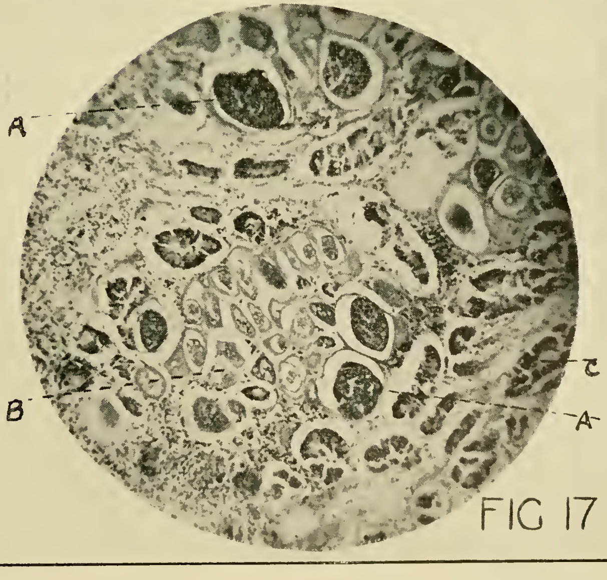

FIG 17

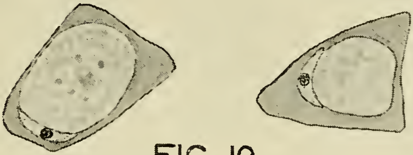

FIG 19

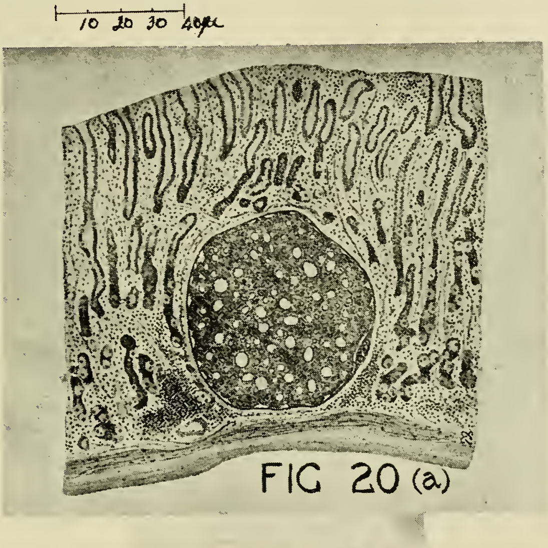

FIG 20 (a)

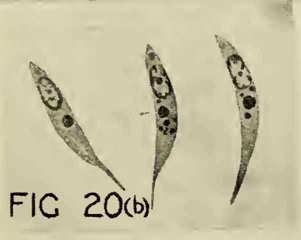

FIG 20(b)

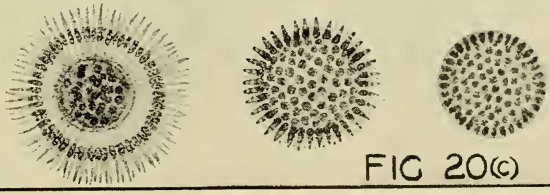

FIG 20(c)

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR, 1911.

The Council herewith presents to Members and Associates of the Society the Annual Report and Details of Receipts and Expenditure for the year 1911.

The following meetings were held:—

March 9th.—Annual Meeting and Election of Officers. At the close of the Annual Meeting an Ordinary Meeting was held. Paper read: "Some Properties of Six Species of Papuan Timbers," by Mr. James Mann. Mr. Mann showed specimens in illustration of his paper, and Mr. A. D. Hardy showed a monoecious example of Casuarina suberosa from Frankston.

April 20th.—Papers read: (1) "A List of Victorian Rotifers, with descriptions of two new species and of the males of two species," by Mr. J. Shepherd; and (2) "The Formation of Fruit Bodies in Polyporus Mylittae," by Professor A. J. Ewart. The authors showed specimens in illustration of their papers, and Mr. A. D. Hardy showed Algae growing in distilled water in a wash bottle.

May 11th.—Papers read: (1) "On Bitter Pit in Apples," by Dr. Jean White; (2) "Contributions to the Flora of Australia, No. 17," by Prof. A. J. Ewart, Miss B. Rees and Miss B. Wood; (3) "The Origin of Cuts on Bones of Australian Extinct Marsupials," by Prof. W. Baldwin Spencer and Mr. R. H. Walcott. Specimens to illustrate the papers were shown by Profs. Ewart and Spencer.

June 8th.—Papers read: (1) "On a New Australian Genus of Phoridae Associated with Termites," by Mr. A. M. Lea; (2) "On a Limburgite Rock, Occurring as a Volcanic Plug at Balwyn, near Doncaster," by Mr. F. Chapman and Mr. A. O. Thiele. Messrs. Chapman and Thiele showed rocks and photographs in illustration of their paper, and Prof. Ewart showed and spoke on a eucalyptus leaf with a red hairy covering.

July 13th.—Papers read: (1) "The Development of the Brain of the Chick," by Miss Kathleen E. Oliver; (2) "The Subdivision of the Spinal Canal in the Region of Chick Embryos," by Miss Helen Kelsey; (3) "New or Little Known Victorian Fossils in the National Museum: Part 13—Some Silurian Species of the Genus Lingula," by Mr. F. Chapman; (4) "Description de quelques nouveaux espèces de Coleptères Australiennes," par M. A. Grouvelle; (5) "On Some New Species of Victorian Mollusca"; and (6) "Additions to and Alterations in the Catalogue of Victorian Marine Mollusca," by J. H. Gatliff and C. J. Gabriel; (7) "Notes on the Geology of Broadmeadows," by Mr. F. L. Stillwell. Mr. Chapman showed specimens of Lingula in illustration of his paper.

August 10th.—Special meeting. The following new law was passed:—Law XLIa. The Council subject to the consent of the author may select any paper for special discussion. Advance proofs of the paper marked confidential shall be sent to those members of the Society desiring copies and to the author for distribution. The selected paper shall have precedence over all other papers to be read at the same meeting. The Council may invite any persons whether members or not to take part in the discussion.

An Ordinary Meeting was then held, when Mr. H. Deane delivered a lecture, entitled "Experiences on the Kalgoorlie-Port Augusta Survey." The lecture was illustrated by a large number of lantern slides.

September 14th.—Papers read: (1) "Some New Australian Cicadidae," by Mr. Howard Ashton; (2) "The Psychrometric Formula," by Dr. E. F. J. Love and Mr. Glenny Smeal. Dr. T. S. Hall showed Lancefieldian graptolites from Preservation Inlet, New Zealand. Prof. E. W. Skeats showed a series of rocks from Heathcote, which exhiibted metasomatism in various stages.

October 12th.—Papers read: (1) "Osmotic Equilibrium in the Living Body," by Dr. J. L. Jona; (2) "Contributions to the Flora of Australia, No. 181," by Prof. A. J. Ewart, Dr. Jean White, Miss Rees and Miss Wood. Mr. Jas. Mann showed curious growth of timber as seen in a planed board, and also growth of callus. Mr. F. H. Baker showed a large specimen of Voluta mammilla and other shells, dredged near Cape Howe.

November 9th.—Papers read: (1) "The Effect of Chemical Substances on the Vitality of Potato Tubers, and their Disinfective Action on Potato Blight (Phytophthora infestans)," by Dr. F. Stoward; (2) "New or Little Known Victorian Fossils in the National Museum: Part 14—Some Silurian Trilobites," by Mr. F. Chapman. Prof. Ewart showed some nodules of sand cemented by limonite, from Gunbower, which exploded on heating. Following is an analysis by Mr. P. Rankin Scott, of the Agricultural Department:—

Moisture - - - -	1.64
Combined water - - -	4.30
Oxides of iron and Aluminium -	15.30
Silica - - - -	77.00
Lime - - -	trace.
Other matter - - -	1.76
	100.00

Dr. J. H. Anderson showed some anthropometrical instruments from the University. Prof. Skeats described specimens of "pine-apple opal" from White Cliffs, exhibited by himself and Dr. Hall. Mr. F. H. Baker showed a large mass of Tenagodes australis, from off Cape Howe, and Mr. Chas. Canwell showed Squilla miles.

December 14th.—Papers read: (1) "On Bitter Pit, and the Sensitivity of Apples to Poison," by Prof. A. J. Ewart; (2) "The Tropics and Pigment," by Dr. Wm. Lowe; (4) "Dioptographic Tracings in Three Normae of Ninety Australian Aboriginal Crania," by Prof. R .J. A. Berry and Dr. A. W. D. Robertson; (5) "Cyst-forming Protozoa in the Intestinal Wall of Marsupials," by Prof. J. A. Gilruth and Mr. L. Bull; (6) "Comparative Bacteriological Examination of Milks Drawn by Hand and by Machine," by Mr. N. MacDonald; (7) "The Anatomy of the Slug, Cystopelta petterdi, var purpurea," by Miss Olive B. Davies; (8) "Protozoa Parasitic in the Large Intestine of Australian Frogs, Part 2," by Miss Janet W. Raff; (9) "On the Monchiquites of Bendigo," by Mr. F. L. Stillwell.

During the year 9 members, 1 country member, and 16 associates were elected; 1 member and 3 associates resigned, and 1 country member and 1 associate have died.

James Oddie was elected a country member in 1882. He was one of the pioneers of Ballarat, and took an active interest in the welfare of the city. He was interested in astronomy, and fitted up an efficient private observatory. Some years previous to his death he presented the whole of the building and instruments to the Ballarat City Council. They were not used, and passed into the hands of the Federal Government, and are being erected at the new capital .

Octavius Albert Sayce was elected an associate in 1898. He contributed several papers to our Proceedings on the anatomy of Gryllotalpa, and on various small crustacea. On the latter forms he was an acknowledged authority, and his papers are widely quoted. For several years and till his death he was assistant lecturer and demonstrator in the Bacteriological Laboratory of the University. His work was characterised by great thoroughness and breadth of view, and his quick sympathetic nature made his a universal favourite. He died very suddenly of pneumonia, and was followed a few weeks later by his wife.

The Proceedings, Vol. XXIII., Pt. 2, and Vol. XXIV., Pt. 1, were published during the year.

The Committee of Management of the National Park, Wilson's Promontory reports that the fence cutting off the Park from the rest of the isthmus has been completed. It is over 7 ft. in height, with an overhanging top, and appears to be quite vermin proof. The track cut by the timber getters for the fence, up Mt. Vereker, has shown the presence of splendid fern gullies, with fine timber. A number of native animals have been introduced. The Government grant has been increased, and many improvements will now be possible.

The Librarian reports the addition of 1884 volumes and parts during the year. The library shows signs of outgrowing its accommodation, and it is hoped that additional building will soon be taken in hand.

Royal Society of Victoria in Account with the Hon. Treas.—March 1st, 1911, to March 1st, 1912.

RECEIPTS.		
To Bank of Australasia — Balance from 1910-11		£124 9 10
Subscriptions—		
Members	£103 17 0	
Associates ...	70 7 0	
Life Members	21 0 0	
		195 4 0
Government Grant		200 0 0
Rents—		
Field Naturalists' Club	£12 0 0	
Comwlth. Government	50 0 0	
		62 0 0
Sale of Books, etc.		2 12 2
Refund fron Gas Co. overpaid		0 5 6
		£584 11 6

EXPENDITURE.		
By Publishing—Printing, &c. ...	£356 17 10	
Assistant Editor	10 0 0	
Distributing	23 10 0	
		£390 7 10
Library—		
Binding	£18 0 0	
Books, &c., Purchased ...	9 14 0	
		27 14 0
Maintainance—		
Rates, Insurance, Lantern, Lighting, &c.	£22 4 9	
Repairs	11 9 0	
Caretaker's A/cs.	17 1 3	
Assist. Secretary's Salary	30 0 0	
Petty Cash, Hon. Sec. ...	5 10 0	
,, ,, Hon. Treas. ...	4 0 0	
		90 5 0
Cash Charges—Commission	£13 14 11	
Bank Charges	0 10 0	
		14 4 11
Bank of Aust. Ltd. Cr. Bal.		61 19 9
		£584 11 6

Compared with Vouchers, and Bank Pass-Book, and found correct,

(Signed) WM. A. HARTNELL,
Hon. Treasurer.

4th February, 1912.

(Signed) JAMES E. GILBERT,
Auditor.

Royal Society of Victoria.

1911.

Patron :

SIR THOMAS GIBSON CARMICHAEL, BART.
afterwards
SIR JOHN FULLER, BART., G.C.M.G.

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PROF. E. W. SKEATS, D.Sc., A.R.C.S.

Vice-Presidents :

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J. SHEPHARD.

Hon. Treasurer :

W. A. HARTNELL.

Hon. Librarian :

R. D. BOYS, B.A.

Hon. Secretary :

T. S. HALL, M.A., D.Sc.

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E. J. DUNN, F.G.S.
PROF. J. A. GILRUTH, D.V.Sc., F.R.S.E.
P. DE J. GRUT.
J. JAMIESON, M.D.
J. A. KERSHAW, F.E.S.
PROF. W. A. OSBORNE, M.B., D.Sc.
W. STAPLEY, M.D., D.V.Sc.
G. SWEET, F.G.S.
R. H. WALCOTT, F.G.S.
E. J. WHITE, F.R.A.S.
F. WISEWOULD.

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THE HON. TREASURER (Convener).
P. de J. GRUT.
G SWEET, F.G.S.

Printing Committee:

THE HON. TREASURER.
PROF. R. J. A. BERRY, M.D., F.R.S.E.

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E. J. WHITE, F.R.A.S.

1911.

LIST OF MEMBERS

WITH THEIR YEAR OF JOINING.

PATRONS.

His Excellency Sir Thomas Gibson-Carmichael, Bart.	1908
His Excellency Sir John Fuller, Bart., G.C.M.G.,	1911

HONORARY MEMBERS.

Forrest, The Hon. Sir J., K.C.M.G., West Australia	1888
Liversidge, Professor A., LL.D., F.R.S., Hornton-street, Kensington, Lond.	1892
Scott, Rev. W., M.A., Kurrajong Heights, N.S.W.	1855
Verbeek, Dr. R. D. M., Speelmanstraat 19, s'Gravenhage, Holland.	1886

LIFE MEMBERS.

Butters, J. S., F.R.G.S., Empire Buildings, Collins-street west, Melb.	1860
Eaton, H. F., 95 Parliament Hill Mansions, Highgate Road, London, N.W.	1857
Fowler, Thos. W., M.C.E., Colonial Mutual Ch., 421 Collins-street, Melb.	1879
Gibbons, Sydney, F.C.S., 31 Gipps-street, East Melb.	1854
Gilbert, J. E., "Melrose," Glenferrie-road, Kew, Vic.	1872
Love, E. F. J., M.A., D.Sc., F.R.A.S., Moreland Grove, Moreland	1888
Nicholas, William, F.G.S.	1864
Selby, G. W., 99 Queen-street, Melb.	1881
Smith, W. Howard, "Moreton," Esplanade, St. Kilda	1911
White, E. J., F.R.A.S., Observatory, Melb.	1868

ORDINARY MEMBERS.

Anderson, J. H., M.B., B.S., Medical School, University, Melb.	1909
Balfour, Lewis, B.A., M.B., B.S., Burwood-road, Hawthorn, Vic.	1892
Baracchi, Pietro, F.R.A.S., Observatory, Melb.	1887
Barnes, Benjamin, Queen's Terrace, South Melb.	1866
Barrett, A. O., "Melisse," Bruce-street, Toorak, Vic. ...	1908
Barrett, Dr. J. W., M.D., M.S. Collins-street	1910
Berry, Prof. R. J. A., M.D., F.R.C.S., F.R.S.E., University, Melb.	1906
Boys, R. D., B.A., Public Library, Melbourne	1903
Brittlebank, C. C., "Queensgate," St. George's-road, Elsternwick	1898
Broome, G. H., State Coal Mine, Wonthaggi	1911
Cameron, S. S., D.V.Sc., Agricultural Dept., Melb.	1910
Cherry, T., M.D., M.S., University, Melbourne.	1893
Clark, D., M.M.E., B.C.E., Education Department, Melbourne.	1910
Cohen, Joseph B., A.R.I.B.A., Public Works Department, Melb.	1877
Dunn, E. J., F.G.S., "Roseneath," Pakington-street, Kew, Vic.	1893
Ewart, Prof. A. J., D.Sc., Ph.D., F.L.S., University, Melb.	1906
Fryett, A. G., care Dr. F. Bird, Spring-street, Melb. ...	1900
Gault, Dr. E. L., M.A., M.B., B.S., Collins-street, Melb.	1899
Gillott, The Hon. Sir S., K.C.M.G., "Edensor," Brunswick-street, Fitzroy, Vic.	1905
Gilruth, Prof. J. A., D.V.Sc., M.R.C.V.S., F.R.S.E., University, Melb.	1909
Grut, P. de Jersey, 125 Osborne-street, South Yarra, Vic.	1901
Hake, C. N., F.C.S., Melbourne Club, Melb.	1890
Hall, T. S., M.A., D.Sc. University, Melb.	1890
Hartnell, W. A., "Irrewarra," Burke-road, Camberwell, Vic.	1900
Harvey, J. H., A.R.V.I.A., 128 Powlett-street, East Melb.	1895
Jamieson, James, M.D., 12 Malvern Road, Toorak. ...	1877

Jones, Dr. W. E., M.R.C.S., "Ludlow," Malvern-road, Toorak	1910
Kelly, Bowes, 70 Queen-street, Melb.	1910
Kendall, E. A., G.M.V.C., "Coniston," Esplanade, Middle Brighton	1910
Kendall, W. T., D.V.Sc., M.B.C.V.S., 36 Park-street, Brunswick.	1911
Kernot, W. N., B.C.E., Working Men's College, Melb.	1906
Kershaw, J. A., F.E.S., National Museum, Melb.	1900
Kitson, A. E., F.G.S., Imperial Institute, S. Kensington, Lond.	1894
Laidlaw, W., B.Sc., Department of Agriculture, Melbourne.	1911
Leach, A. J., M.Sc., Education Department, Melb.	1904
Lyle, Prof. T. R., M.A., D.Sc., University, Melb.	1889
Loughrey, B., M.A., M.D., Ch.B., M.C.E., 1 Elgin-street, Hawthorn, Vic.	1880
Lowe, W., M.B., B.S., Royal Parade, Parkville	1911
MacDonald, N., Veterinary School, Parkville	1911
MacKenzie, Colin W. M.D., B.S., F.R.C.S., Collins-street, Melb.	1910
Masson, Prof. Orme, M.A., D.Sc., F.R.S.E., F.R.S., University, Melb.	1887
Merrill, A. P., D.D.S., Collins-street, Melbourne	1911
Michell, J. H., M.A., F.R.S., University, Melb.	1900
Nanson, Prof. E. J., M.A., University, Melb.	1875
Oliver, C. E., M.C.E., Metropolitan Board of Works, Melb.	1878
Osborne, Prof. W. A., M.B., Ch.B., D.Sc., University, Melb.	1910
Payne, A. T., "Scotsburn," Toorak	1911
Payne, Prof. H., M.I.C.E., M.I.M.E., University, Melb.	1910
Petherick, E.A., F.R.G.S., F.L.S., 254 Albert-street, East Melbourne.	1910
Robertson, A. W. D., M.D., B.S., University, Melb.	1909
Robertson, W. A., G.M.V.C, Agricultural Dept., Melb.	1910
Rowe, W. C., "Invicta," Chaucer-street, Canterbury, Vic.	1908
Schlapp, H. H., 31 Queen-street, Melb.	1906
Shephard, John, Clarke-street, South Melb.	1894
Skeats, Prof. E. W., D.Sc., University, Melb.	1905

Spencer, Prof. W. Baldwin, C.M.G., M.A., F.R.S., University, Melb.	1887
Stapley, W., M.D., D.V.Sc., M.R.C.V.S., Veterinary School, University, Melb.	1910
Sweet, George, F.G.S., Wilson-street, Brunswick, Vic. ...	1887
Swinburne, The Hon. G., M.L.A., "Shenton," Kinkora-road, Hawthorn, Vic.	1905
Taylor, R., 31 Queen-street, Melb.	1907
Walcott, R. H., F.G.S., Technological Museum, Melb. ...	1897
Ware, S., M.A., Education Department, Melb.	1901
Wisewould, F., 408 Collins-street, Melb.	1902

Country Members.

Blackburne, J., Inspector of Forests, Maryborough, Vic.	1911
Desmond, J., R.V.S., G.M.V.C., "Ellerslie," Hurtle-square, Adelaide, S.A.,	1901
Gregory, Prof. J. W., D.Sc., F.R.S., University, Glasgow	1900
Hart, T. S., M.A., B.C.E., F.G.S., School of Mines, Ballarat, Vic.	1894
Hogg, H. R., M.A., 2 Vicarage Gate, Kensington, W. ...	1890
Ingram, Alex., Hamilton, Vic.	1903
Lea, A. M., F.E.S., Museum, Adelaide, S.A.	1909
Maplestone, C. M., Eltham, Victoria	1898
Mennell, F. P., Rhodesian Museum, Buluwayo, South Africa	1902
Murray, Stuart, C.E., "Morningside," Kyneton, Vic. ...	1874
Thom, L. N., B.Sc., Shepparton, Vic.	1910

Corresponding Members.

Bailey, F. M., F.L.S., Government Botanist, Brisbane, Queensland	1880
Dendy, Professor Arthur, D.Sc., F.R.S., Sec.L.S., King's College, London	1888
Etheridge, Robert, Junr., Australian Museum, Sydney, N.S.W.	1877

Lucas, A. H. S., M.A., B.Sc., Sydney Grammar School, Sydney, N.S.W.	1895
Stirton, James, M.D., F.L.S., 15 Newton-street, Glasgow	1880

ASSOCIATES.

Abbott, S. B., 67 Pakington-street, Kew	1910
Armitage, R. W., B.Sc., Continuation School, East Melb.	1907
Ashton, H., "Argus" Office	1911
Audas, J. W., "Engowra," Punt-road, St. Kilda	1911
Bage, Mrs. Edward, "Cranford," Fulton-street, St. Kilda, Vic.	1906
Bage, Miss F., M.Sc., Fulton-street, St. Kilda, Vic.	1906
Baker, F. H., 167 Hoddle-street, Richmond	1911
Baker, Thomas, Bond-street, Abbotsford, Vic.	1889
Bale, W. M., F.R.M.S., Walpole-street, Hyde Park, Kew, Vic.	1887
Bennetts, W. R. Pakington-street, Kew, Vic.	1894
Barkley, H., 9 Denham-street, Hawthorn	1910
Booth, John, M.C.E., B.Sc., "Ambergate," Wallace Avenue, Toorak, Vic.	1872
Breidahl, H., 36 Rouse-street, Port Melbourne	1911
Brodribb, N. K. S., Cordite Factory, Maribyrnong	1911
Brook, R. H. T.	1906
Buchanan, Miss G., M.Sc., University, Melb.	1910
Canwell, C., c/o Mr. Penrose, Hoddle-street, Richmond	1911
Chapman, F., A.L.S., National Museum, Melb.	1902
Corbett, J., "Clifton," 39 Rushall-crescent, N. Fitzroy, Vic.	1907
Danks, A. T., 391 Bourke-street West, Melb.	1883
Davies, Miss O. B., B.Sc., Mentone Parade, Mentone	1911
Fenton, J. J., 89 Royal Parade, Parkville	1910
Ferguson, W. H., 59 Brinsley-road, E. Camberwell	1894
Finney, W. H., 40 Merton-street, Albert Park, Vic.	1881
Foubister, J. J., 45 Queen's Parade, Clifton Hill	1911
Foxcroft, A. B., Public Library, Melbourne	1911
Fulton, S. W., 369 Collins-street, Melb.	1900
Gabriel, C. J., Victoria-street, Abbotsford, Vic.	1908
Gabriel, J., "Cwmdar," Walmer-street, Kew	1887
Gatliff, J. H., 32 Morrah-street, Parkville	1898
Green, W. Heber, D.Sc., University, Melb.	1896
Grayson, H. J., University, Melb.	1902

Hamilton, J. T., F.L.S., "Brooklyn," Heidelberg-road, Ivanhoe.	1910
Hardy, A. D., F.L.S., Lands Department, Melb.	1903
Herman, Hyman, B.C.E., F.G.S., 60 Queen-stret, Melb.	1897
Hoadley, C. A., B.Sc., "Bella Vista," Cotham-road, Kew	1910
Howitt, A. M., 61 Denbigh-street, Armadale	1910
Hunter, S. B., Department of Mines, Melb.	1908
Jobbins, G. G., Electric Lighting and Traction Co., Geelong, Vic.	1902
Joshua, E. C., 906 Malvern-road, Armadale	1911
Jutson, J. T., Geological Survey, Perth, W.A.	1902
Keble, R. A., "St. Leonards," Glassford-street, Toorak	1911
Kenyon, Mrs. A. F., 291 Highett-street, Richmond, Vic.	1908
Kenyon, A. S., Heidelberg, Vic.	1901
Lambert, Thomas, Bank of New South Wales, Benalla, Vic.	1890
Lewis, J. C., L.V.Sc., Darwin, N.T.,	1910
Luly, W. H., Department of Lands, Treasury, Melb.	1896
Mickle, K. A., "Illira," Marine Parade, St. Kilda	1911
Mitchell, S. R.	1908
Maclean, C. W., "Bronte," Strand, Williamstown, Vic.	1879
Mahoney, D. J., M.Sc., Dept. Mines, Melbourne	1904
McKenzie, G. Lands Department, Melb.	1907
McNab, V. R., "Almaden," Kooyong-road, Caulfield	1910
Miller, E. E., Boundary-road, Toorak, Vic.	1908
Nicholls, E. B., 164a Victoria-street, North Melb.	1904
Oliver, Miss K. K., Gunnedah, N.S.W.	1910
O'Neill, W. J., Lands Department, Melb.	1903
Ower, L. H., State Coal Mine, Wonthaggi	1910
Philpots, G., E.P., D.D.S., M.A.G.D., 110 Collins-street, Melbourne.	1911
Pritchard, G. B., D.Sc., F.G.S., "Talavera," 6 Kooyongkoot-road, Hawthorn.	1892
Raff, Miss J., M.Sc., University, Melb.	1910
Rees, Miss B., University, Melb.	1910
Richards, H. C., M.Sc., Central Technical College, Brisbane, Queensland	1909
Ritchie, E. G., Assoc. M.I.C.E., Met. Board of Works, Melb.	1909
Rivett, A. C. D., B.A., B.Sc., University, Melbourne	1911
Roberts, R. D., "Braemar," Stirling-street, Kew	1909

Sayce, O. A.	1898
Schafer, R., "Invercloy," Napier-street, Essendon, Vic.	1883
Smeal, G., B.Sc., University, Melbourne	1911
Smith, J. A., 15 Collins-place, Melb.	1905
Stillwell, F. L., B.Sc.	1910
Summers, H., M.Sc., 49 Airlie-street, S. Yarra, Vic.	1902
Sutton, C. S., M.B., B.S., Rathdown-street, N. Carlton, Vic.	1908
Sutherland, Ian M., M.C.E., "Novar," Dandenong, Vic.	1905
Sweet, Miss G., D.Sc., Wilson-street, Brunswick, Vic.	1906
Thorn, Wm., Mines Department, Melb.	1907
Thiele, E. O., M.Sc., c/o O. A. Thiele, "Evandale," Chatham-road, Canterbury, Vic.	1898
Tovey, J. R., National Herbarium, South Yarra	1911
Traill, J. C., B.A., B.C.E., "Osmington," Domain-road, South Yarra, Vic.	1903
Wedeles, James, 231 Flinders-lane, Melb.	1896
White, Miss R. E. J., D.Sc., Observatory Quarters, S. Yarra, Vic.	1908
Wilkinson, H. L., M.C.E., Equitable Buildings, Melb.	1909
Woodward, J. H., Queen's Buildings, Rathdown-street, Carlton, Vic.	1903

LIST OF THE INSTITUTIONS AND LEARNED SOCIETIES THAT RECEIVE COPIES OF THE "TRANSACTIONS" AND "PROCEEDINGS" OF THE ROYAL SOCIETY OF VICTORIA.

1911.

Argentina.

Academia Nacional de Ciencias Exactas	Cordoba
Museo de La Plata	Buenos Ayres

Australian Commonwealth.

Central Weather Bureau	Melbourne
Federal Parliamentary Library	Melbourne

Austro-Hungary.

K. Akademie der Wissenchaften	Vienna
K. K. Geographische Gessellschaft	Vienna
K. K. Geologische Reichsanstalt	Vienna
K. K. Gradmessungs-Bureau	Vienna
K. K. Naturhistorisches Hofmuseum	Vienna
K. K. Sternwarte	Prague
Siebenburgischer Verein fur Naturwissenschaften	Hermannstadt

Belgium.

Académie Royale des Sciences de Belgique	Bruxelles
Ministère des Sciences and des Arts	Bruxelles
Société Belge de Geologie	Bruxelles
Société Géologique de Belgique	Liége
Société Royale Zoologique Malacologique de Belgique	Bruxelles

Brazil.

Commissão Geographica e Geologica do Estado de S. Paulo	S. Paulo.
Museu Paulista	S. Paulo
Sociedade Scientifica	S. Paulo

CANADA.

Canadian Institute	Toronto
Geological Survey of Canada	Ottawa
Legislative Library	Victoria, B.C.
McGill University	Montreal
Nova Scotian Institute of Science	Halifax
Parliamentary Library	Ottawa
Royal Society of Canada	Montreal

CAPE COLONY.

Albany Museum	Grahamstown
Geological Commission	Capetown
South African Museum	Capetown
S. African Assoc. for the Advancement of Science	Capetown
Royal Society of South Africa	Capetown

DENMARK.

Kon. Danske Videnskabernes Selskab	Copenhagen

ENGLAND.

Agent-General of Victoria	London
Anthropological Institute	London
Balfour Library	Cambridge
Bodleian Library	Oxford
Bristol Naturalists' Society	Bristol
British Museum	London
British Museum (Natural History)	London
Colonial Office Library	London
Conchological Society of Great Britain and Ireland	Manchester
Geological Society	London
Geologists' Association	London
Imperial College of Science and Technology	South Kensington
Institute of Mining and Mechanical Engineers	Newcastle
Linnæan Society	London
Literary and Philosophical Society	Manchester
Liverpool Biological Society	Liverpool
Liverpool Literary and Philosophical Society	Liverpool
Manchester Museum, Owens College	Manchester
Marine Biological Laboratory	Plymouth
National Physical Laboratory	Teddington, Middlesex
"Nature"	London
Patent Office, 25 Southampton Buildings	London
Philosophical Society	Cambridge
Physical Society	London

Royal Colonial Institute	London
Royal Botanic Gardens	Kew
Royal Geographical Society	London
Royal Microscopical Society	London
Royal Society	London
"Science Abstracts"	London
University College	London
University library	Cambridge
Zoological Society	London

FRANCE.

Académie des Sciences, Belles Lettres et Arts	Lyon
Faculté des Sciences	Marseilles
Feuille des Jeunes Naturalistes	Paris
Laboratoire de Zoologie et de Physiologie Maritimes	Concarneau
Société des Sciences Naturelles de l'Ouest de la France (Museum)	Nantes
Société Geologique du Nord	Lille
Société Nationale de Cherbourg	Cherbourg
Société Zoologique de France	Paris
Station Zoologique de Cette	Cette (Hérault)
Université de Rennes	Rennes

GERMANY.

Deutsche Geologische Gesellschaft	Berlin
Gesellschaft fur Erdkunde	Berlin
Jenaische Zeitsch. f. Medicin und Naturwissenschaft	Jena
Königl.-bäyer. Akademie der Wissenchaften	Munich
Königl. Biologische Anstalt	Helgoland
Kön. Zoologisches Museum	Berlin
Königl. Offentl. Bibliothek	Dresden
Königl. Preussische Akademie der Wissenschaften	Berlin
Königl. Sächs. Gesellschaft der Wissenschaften	Leipzig
Königl. Gesellschaft der Wissenschaften	Göttingen
Museum für Natur-und Heimatkunde	Magdeburg
Naturforschende Gesellschaft	Emden
Naturforschende Gesellschaft	Freiburg i. Breisgau
Naturforschende Gesellschaft	Leipzig
Naturforschende Gesellschaft	Rostock
Naturhistorisch-Medicinischer Verein	Heidelberg
Naturhistorische Gesellschaft	Nürnberg
Naturhistorisches Museum	Hamburg
Naturhistorischer Verein der Preussischen Rheinlande und Westfalens	Bonn

Naturwissenschaftlicher Verein	Bremen
Oberhessische Gesellschaft für Natur u. Heilkunde	Giessen
Physikalisch-medicinische Gesellschaft	Wurzburg
Provinzial Museum	Hannover
Schlesische Gesellschaft für vaterländische Cultur	Breslau
Senckenbergische Naturforschende Gesellschaft	Frankfurt am M.
Verein für Erdkunde	Halle
Verein für Naturkunde	Kassel
Zeitschr. für wissenschaftliche Insekten-Biologie	Berlin

HAWAIIAN ISLANDS.

Bernice Pauahai Bishop Museum	Honolulu

HOLLAND.

Musée Teyler	Haarlem
Nederlandsche Botanische Vereeniging	Nijmegen
Rijks Geologisch-Mineralogisch Museum	Leyden
Rijks Herbarium	Leiden
Société Provinciale des Arts et Sciences	Utrecht

INDIA.

Agricultural Research Institute	Pusa
Asiatic Society of Bengal	Calcutta
Geological Survey of India	Calcutta
Indian Museum	Calcutta
Royal Asiatic Society, Ceylon Branch	Colombo

IRELAND.

Belfast Natural History and Philisophical Society	Belfast
Royal Dublin Society	Dublin
Royal Irish Academy	Dublin
Trinity College Library	Dublin

ITALY.

Biblioteca Nazionale Vittorio Emanuele	Rome
Istituto Zoologico, R. Università	Naples
Laboratorio de Zoologia generale e agraria	Portici
Musei di Zoologia ed Anatomia Comp., R. Università	Turin
Ministero dei Lavori Pubblici	Rome
Reale Accademia dei Lincei	Rome
R. Accademia delle Scienze dell' Istituto	Bologna
Reale Accademia di Scienze	Palermo

Reale Accademia di Scienze, Lettere ed Arti	Lucca
Regia Accademia di Scienze, Lettere ed Arti	Modena
Società Geologica Italiana	Rome
Società Geografica Italiana	Rome
Società Toscana di Scienze Naturali	Pisa
Zoological Station	Naples

JAPAN.

Imperial University	Tokio
Kyōto Imperial University	Kyōto
Tohoku Imperial University	Sendai

JAVA.

Bataviaasch Genootschap van Kunsten en Wetenschappen	Batavia
Koninkl. Natuurkundige Vereeniging	Batavia
Royal Magnetical and Meteorological Observatory	Batavia

MEXICO.

Instituto Geologico de Mexico	Mexico
Ministerio de Fomento	Mexico
Museo Nacional	Mexico
Sociedad Científica "Antonio Alzate"	Mexico

NATAL.

Durban Museum	Durban
Government Museum	Pietermaritzburg

NEW SOUTH WALES.

Australian Museum	Sydney
Astronomical Observatory	Sydney
Botanic Gardens	Sydney
Department of Agriculture	Sydney
Department of Fisheries	Sydney
Department of Mines	Sydney
Linnæan Society of New South Wales	Sydney
New South Wales Naturalists' Club	Sydney
Parliamentary Library	Sydney
Public Library	Sydney
Royal Anthropological Society of Australasia	Sydney
Royal Society	Sydney
Sydney University Engineering Society	Sydney
Technological Museum	Sydney
University Library	Sydney

NEW ZEALAND.

Auckland Institute and Museum	Auckland
Dominion Museum	Wellington
Geological Survey	Wellington
Museum	Christchurch
New Zealand Institute	Wellington
Otago Institute	Dunedin
Parliamentary Library	Wellington
Public Library	Wellington

NORWAY.

Archiv for Mathematik og Naturvidenskab	Christiania
Bergens Museum	Bergen
Kon. Norsk Fredricks Universitet	Christiania
Nyt Magazin for Naturvidenskaberne	Christiania
Videnskabs-Selskabet	Christiania

PERU.

Cuerpo de Ingenieros de Minas del Peru	Lima

PHILIPPINE ISLANDS.

Bureau of Science (Department of Interior)	Manila

PORTUGAL.

Academia de Sciencias de Portugal	Lisbon
Sociedade de Geographia	Lisbon

QUEENSLAND.

Geological Survey Office	Brisbane
Paliamentary Library	Brisbane
Queensland Museum	Brisbane
Royal Geographical Society	Brisbane
Royal Society of Queensland	Brisbane

RHODESIA.

Rhodesia Museum	Buluwayo

ROUMANIA.

Institut Météorologique de Roumanie	Bucharest

RUSSIA.

Académie Impériale des Sciences	St. Petersburg
Comité Géologique de Russie	St. Petersburg
Commission Géologique de Finlande	Helsingfors
Jardin Botanique Imperial	St. Petersburg
Minister of Agriculture, St. Petersburg, c/o Russian Consulate	Melbourne
Societas Scientiarum Fennica	Helsingfors, Finland
Société des Naturalistes de l'Université de Kasan	Kasan
Société des Naturalistes	Kiew
Société des Naturalistes de la Nouvelle Russie	Odessa
Société Impériale des Naturalistes	Moscow
Société Impériale Russe de Geographie	St. Petersburg
Station Biologique	Sebastopol

SCOTLAND.

Botanical Society	Edinburgh
Geological Society	Edinburgh
Royal College of Physicians' Laboratory	Edinburgh
Royal Philosophical Society	Glasgow
Royal Physical Society	Edinburgh
Royal Scottish Geographical Society	Edinburgh
Royal Scottish Society of Arts	Edinburgh
Royal Society	Edinburgh
University Library	Edinburgh
University Library	Glasgow

SOUTH AUSTRALIA.

Parliamentary Library	Adelaide
Public Library and Museum	Adelaide
Royal Geographical Society	Adelaide
Royal Society of South Australia	Adelaide
University Library	Adelaide

SPAIN.

Real Academía de Ciencias exactas, físicas y naturaes	Madrid

SWEDEN.

Entomolgiska Föreningen	Stockholm
Kongl. Universitets Bibliotek	Upsala
Kongl. Vetenskaps Akademi	Stockholm
Kongl. Vitterhets Historie och Antiquitets Akademi	Stockholm
Kungl. Vetenskaps och Vitterhets Samhälle	Göteborg
Sveriges Geologiska Undersökning	Stockholm
Zootomisches Institut der Universität	Stockholm

SWITZERLAND.

Geographische Gesellschaft	Berne
Naturforschende Gessellschaft	Basel
Naturforschende Gesellschaft	Zürich
Schweizerische Naturforschende Gesellschaft	Berne
Société de Physique et d'Histoire Naturelle	Genève

TASMANIA.

Geological Survey	Launceston
Parliamentary Library	Hobart
Public Library	Hobart
Royal Society of Tasmania	Hobart

UNITED STATES OF AMERICA.

Academy of Natural Sciences	Philadelphia
American Institute of Mining Engineers	New York
American Microscopical Society	
American Museum of Natural History, Central Park	New York
American Academy of Arts and Sciences	Boston
American Geographical Society	New York
American Philosophical Society	Philadelphia
Bureau of Ethnology, Smithsonian Institute.	Washington, D.C.
Bureau of Standards	Washington
California Academy of Sciences	San Francisco, Cal.
Connecticut Academy of Arts and Sciences	New Haven
Cooper Union for the Advancement of Science and Art	New York
Davenport Academy of Natural Sciences	Davenport, Iowa
Department of Agriculture	Washington, D.C.
Field Museum of Natural History	Chicago
Geographical Society of Philadelphia	Philadelphia
Geological Survey	Iowa
Iowa Academy of Sciences	Iowa
Johns Hopkins University	Baltimore
Leland Stanford Junior University	San Francisco
Lloyd Museum and Library	Cincinnati, Ohio
Maryland Geological Survey	Baltimore
Missouri Botanical Garden	St. Louis
Museum of Brooklyn Institute of Arts and Sciences	Brooklyn, N.Y.
Museum of Comparative Zoology	Cambridge
New York Public Library	New York

Philosophical Society	Washington, D.C.
St. Louis Academy of Science	St. Louis
"Science"	New York
Smithsonian Institution	Washington, D.C.
Society of Natural History	Boston
Society of Natural Sciences	Buffalo
State Library	Albany, N.Y.
State Geological Survey	Grand Forks, N. Dakota
State Laboratory of Natural History	Urbana, Illinois
Texas Academy of Sciences	Austin, Tex.
Tufts College	College Hill, Massachusetts
United States Geological Survey	Washington, D.C.
U.S. Coast and Geodetic Survey	Washington
University of California	Berkeley, Cal.
University of Chicago	Chicago
University of Kansas	Lawrence, Kan.
University of Michigan	Ann Arbor, Mich.
University of Missouri	Columbia, Mo.
Wagner Free Institute of Science	Philadelphia
Wisconsin Academy of Sciences, Arts and Letters	Madison, Wis.
Wistar Institute of Anatomy and Biology	Philadelphia

Uruguay.

Museo Nacional	Montevideo

Victoria.

"Age"	Melbourne
"Argus"	Melbourne
Astronomical Observatory	Melbourne
Australasian Institute of Mining Engineers	Melbourne
Chief Secretary's Office	Melbourne
Department of Agriculture (Pathologist's Branch)	Melbourne
Department of Agriculture (Editor's Branch)	Melbourne
Department of Mines and Water Supply	Melbourne
Field Naturalists' Club of Victoria	Melbourne
Free Library	Geelong
Government Entomologist	Melbourne
Government Statist	Melbourne
Medical Society of Victoria	Melbourne
National Herbarium	Melbourne
National Museum	Melbourne
Parliamentary Library	Melbourne
Pharmaceutical Society of Australasia	Melbourne
Public Library	Melbourne

Public Museum	Warrnambool
Royal Australasian Ornithologists' Union	Melbourne
Royal Geographical Society	Melbourne
School of Mines	Ballarat
School of Mines	Bendigo
Society of Chemical Industry of Victoria	Melbourne
Prahran Public Library	Prahran
University Library	Melbourne
Victorian Institute of Engineers	Melbourne
Victorian Institute of Surveyors	Melbourne
Working Men's College	Melbourne

WESTERN AUSTRALIA.

Geological Survey Office	Perth
Natural History and Science Society	Perth
Western Australian Museum and Art Gallery	Perth
Victoria Public Library	Perth

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